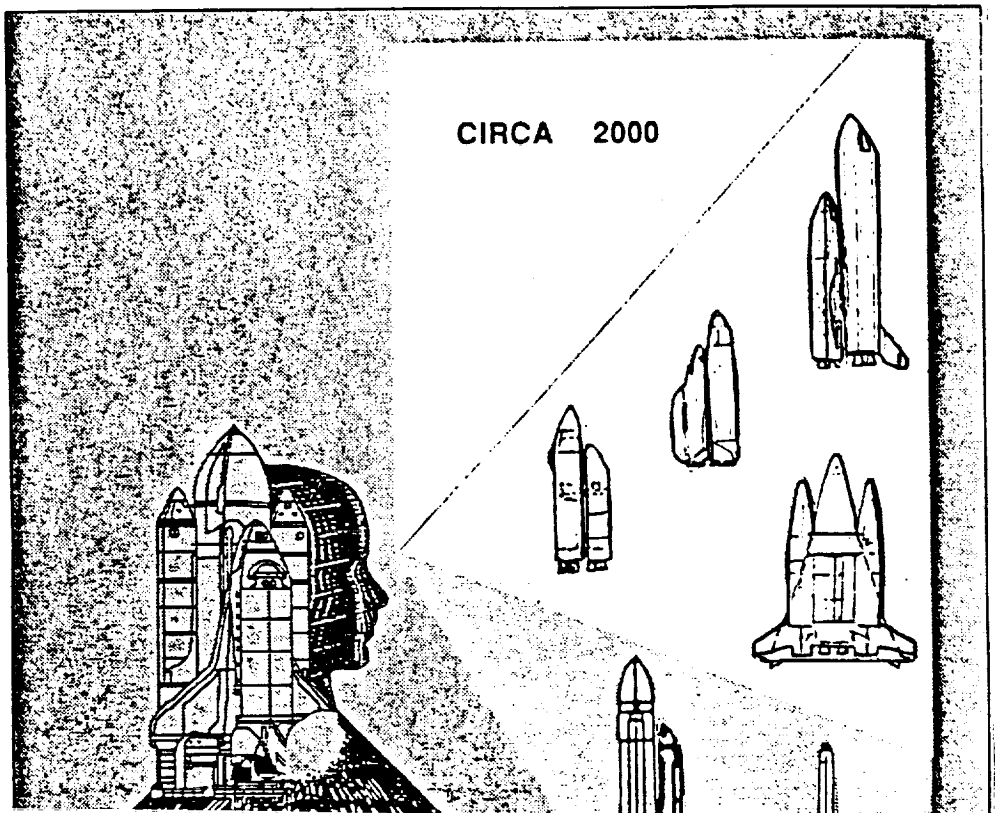
Shuttle Ground Operations Efficiencies/Technologies Study

BOEING

AEROSPACE OPERATIONS



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FINAL REPORT PHASE 2
Volume 6 of 6

CIRCA 2000 SYSTEM

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SHUTTLE GROUND OPERATIONS EFFICIENCIES / TECHNOLOGIES STUDY

PHASE 2 FINAL REPORT

STUDY REPORT

Volume 1 EXECUTIVE SUMMARY

The Executive Summary provides an overview of major elements of the Study. It summarizes the Study analytic efforts, the documentation developed, and reviews the recommendations resulting from the analyses conducted during Phase 2 of the Study.

Volume 2 PHASE 2 FINAL ORAL PRESENTATION

The Final Presentation Material volume contains the charts used in the Final Oral Presentations for Phase 2, at KSC on April 6, 1988. A brief, overall review of the Study accomplishments is provided. An indepth review of the documentation developed during the last quarter of Phase 2 of the Study is presented. How that information was used in this Study is explained in greater detail in Vols. 3 and 4. An initial look at the topics planned for the upcoming Workshops for Government/Industry is presented along with a cursory look at the results expected from those Workshops.

Volume 3 SPACE-VEHICLE OPERATIONAL COST DRIVERS HANDBOOK (SOCH)

The Space-vehicle Operational Cost drivers Handbook (SOCH) was assembled early in Phase 2 of the Study as one of the fundamental tools to be used during the rest of the Phase. The document is made up of two parts -- packaged separately because of their size.

Part 1 Presents, in checklist format, the lessons learned from STS and other programs. The checklist items were compiled so that the information would be easily usable for a number of different analytical objectives, and then grouped by disciplines or gross organizational, and/or functional responsibilities. Content of the checklists range from 27 management; 11 system engineering; 8 technology; and 19 design topics -- with a total of 793 individual checklist items. Use of this Handbook to identify and reduce Cost Drivers is recommended for designers, Project and Program managers, HQ Staff, and Congressional Staffs.

Part 2 Contains a compilation of related reference information about a wide variety of subjects including ULCE, Deming, Design/Build Team concepts as well as current and previous space launch vehicle programs. Information has been accummulated from programs that range from, Saturn/Apollo, Delta, Titan , and STS to NASP and Energia.

Volume 4 SIMPLIFIED LAUNCH SYSTEM OPERATIONAL CRITERIA (SLSOC)

The SLSOC document was developed from the generic Circa 2000 System document, Vol. 6; is similar in content; and also indicates the manpower effect of the elimination of many STS-type cost drivers. The primary difference between the two documents is the elimination of all generic Circa 2000 requirements (and support) for manned-flight considerations for the ALS vehicle. The data content of the two documents, while similar in nature, was reorganized and renumbered for SLSOC so that it could be used as the basis for various panels and subpanels in an ALS Workshop.

Historical data is the basis for the conclusion that incremental improvements of technology and methods cannot significantly improve LCC (by an order-of-magnitude) without major surgery. A system enabling the development of a radically simplified operational concept, reflected in SLSOC, was included so that proposed designs (and operations) could be compared to systems providing for simplicity -- rather than the current STS complexity.

The identified operational cost drivers from STS plus other historical data were used as background reference information in the development of each example concept designed to eliminate cost drivers. These example concepts, when integrated, would support an order-of-magnitude cost reduction in current (STS), exorbitant Life Cycle Costs (LCC). Individual operational requisites were developed for each element in the associated management systems, integration engineering, vehicle systems, and supporting facilities. These have associated rationale, sample concepts, identification of technology developments needed, and technology references to abstracts. The technology abstracts are provided in a separate volume, Vol. 5.

Technology changes almost daily, thus past trade studies may no longer be valid. In addition, old "trades" often used inaccurate estimates of "real" operational costs. Vehicle designs are compromises and have been performance oriented with operations methods/techniques based on those designs. It is the intent of our example concepts in the SLSOC to stimulate design teams to improve or replace conventional design approaches. Obviously, it is up to the responsible program design teams to provide design solutions to resolve operational cost drivers.

Volume 5 TECHNOLOGY REFERENCES

This document provides a repository for the Technology References for the SLSOC and the CIRCA 2000 System documents. The technology references, mostly from NASA RECON, are supplied to the reader to facilitate analysis on either the SLSOC or the CIRCA 2000 System documents. Some data references were also obtained via DIALOG. If more technical information is desired by an analyst, he must obtain the additional documentaiton thru his library or from some other appropriate source. The XTKB (EXpanded Technology Knowledge Base) provided a user-friendly tool for our analyses in identifying and obtaining the computerized database reference information contained in this document. Thousands of abstracts were screened to obtain the 300 plus citations pertinent to SLSOC in this Volume.

Volume 6 CIRCA 2000 SYSTEM OPERATIONAL REQUIREMENTS

The Circa 2000 System Operations Requirements were developed using STS as a working data source. We identified generic operations cost drivers resulting from performance-oriented vehicle design compromises and the operations methods/techniques based on those designs. Those Cost Drivers include high-cost, hazardous, time & manpower-consuming problem areas involving vehicles, facilities, test & checkout, and management / system engineering. Operational requisites containing rationale, example concepts, identification of technology developments needed, and identification of technology references using available abstracts were developed for each Cost Driver identified. Elimination of cost drivers significantly reduces recurring costs for prelaunch processing and launch operations of space vehicles.

NOTE: Volumes 1,3,4 and 5 are being widely distributed. Volume 2 is a copy of presentation material already distributed and Volume 6 will be distributed only on request. Copies of the full report will be placed in libraries at NASA HQ., JSC, KSC, MSFC and NASA RECON. Individual volume copies may be obtained by forwarding a request to W. J. Dickinson, KSC PT-FPO, (305) 867-2780.

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ACRONYMS and ABBREVIATIONS

\$B	Dollars-billions
\$M	Dollars-millions
AFD	Aft Flight Deck
AFSATCOM	Air Force Satellite Communications
AFSCF	Air Force Satellite Control Facility
AFSCN	Air Force Satellite Control Network
AFSCF/STC	Air Force Satellite Control Facility/Space Test Ctr.
AGCS	Automatic Ground Control System
AH	Ampere-Hour
AI	Artificial Intelligence
Al	Aluminum
Al-Li	Aluminum-Lithium
AOA	Abort Once Around
APU	Auxiliary Power Unit
ASE	Airborne Support Equipment
ASSY	Assembly
ATC	Air Traffic Control
ATE	Automatic Test Equipment
ATKB	Automation Technology Knowledge Base
ATO	Abort to Orbit
ATPG	Automatic Test Program Generation
A50	Aerozine 50 (50% Hydrazine and 50% UDMH)
BIT	Built-In-Test
BITE	Built-In-Test-Equipment
BSTR	Booster
C	Celsius; Carbon
C2K	Circa 2000
C_3H_8	Propane
CAD	Computer Aided Design
CAE	Computer Aided Engineering
CAI	Computer Aided Instruction
CALS	Computer Aided Logistics System
CAM	Computer Aided Manufacturing
CDDT	Countdown Demonstration Test
CDF	Confined Detonating Fuse
CECO	Center Engine Cutoff
CELV	Complimentary Expendable Launch Vehicle (now Titan IV)
CG	Center of Gravity
CH_4	Methane
CIM	Computer Integrated Manufacturing
CITE	Cargo Integration Test Equipment
CIU	Computer Interface Unit
CM	Command Module
C/O	Checkout
COMM	Communications
COMM SAT	Communication satellite
CPU	Central Processing Unit
CPV	Combined Pressure Vessel
CR	Control Room
Cryo	Cryogenic
CSOC	Consolidated Space Opertions Center
CT	Crawler Transporter
CTS	Common Tank Set
CV	Cargo Vehicle
CVD	Chemical Vapor Deposition

ACRONYMS and ABBREVIATIONS
(Continued)

DA	Data Acquisition
D/A	Digital/Analog
DAS	Data Acquisition System
DB	Data Base
DBMS	Data Base Management System
DBS	Direct Broadcast Satellite
DBT	Design Build Team
dc	Direct Current
DCA	Defense Communications Agency
DDT&E	Design, Development, Test and Evaluation
DFT	Design For Testability DMS Data Management System
DOD,DoD	Department of Defense
DOMSAT	Domestic Communication Satellite
DPS	Data Processing System
DR	Discrepancy Report
DSCS	Defense Satellite Communication System
DSN	Deep Space Network DSP Defense Support Program
DTC	Design to Cost
ECLSS	Environmental Control & Life Support System
ECS	Environmental Control System
EECOM	Electrical, Environmental, Communications
EIU	Engine Interface Unit
ELS	Eastern Launch Site
ELV	Expendable Launch Vehicle
EMC	Electro Magnetic Compatibility
EMU	Extravehicular Mobilility Unit; Extended Memory Unit
EPD&C	Electrical Power Distribution and Control
EPS	Electrical Power Subsystem
ES	Expert System
ESS	Energy Storage System
E/T	External Tank
ETR	Eastern Test Range
EVA	Extravehicular Activity
FAA	Federal Aviation Administration
FCE	Flight Crew Equipment
FCM	Fuel Cell Module
FDO	Flight Dynamics Officer
FMS	Flight Management System
FRCS	Forward Reaction Control System
FSS	Flight Systems Simulator
FWC	Filament Wound Case
FY	Fiscal Year
GB	Ground Based
GD	General Dynamics
GEO	Geosynchronous Orbit
GFS	Government Furnished Support
GH2, GH_2	Gaseous Hydrogen
GLOW	Gross Liftoff Weight
GN&C,G&C	Guidance Navigation and Control
GN_2	Gaseous Nitrogen
GO	Ground Operations
GO2,GO_2	Gaseous Oxygen
GPM	Gallons Per Minute
GPS	Global Positioning Satellite
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center

ACRONYMS and ABBREVIATIONS
(Continued)

GSTDN,STDN	Ground Station Tracking and Data Network
HC	Hydrocarbon
He	Helium
HEO	High Earth Orbit
HIF	Horizontal Integration Facility
HLLV	Heavy Lift Launch Vehicle
HPFTP	High Pressure Fuel Turbo Pump
HTO	Horizontal Take Off
H/W	Hardware
H_2	Hydrogen
HYD	Hydraulic(s)
IC	Integrated Circuit
IDSS	Integrated Design Support System
I/F	Interface
IMIS	Integrated Maintenance Information System
IFA	In-flight Anomaly
ILS	Integrated Logistics System
IMU	Inertial Measurement Unit
INCO	Instrumentation and Communications Officer
INEL	Idaho National Engineering Laboratory
INS,INST	Instrumentation
INT	Integration
IOC	Initial Operational Capability
I/O	Input/Output
IPR	Interim Problem Report
IPV	Individual Pressure Vessel
IR	Infrared
IR&D	Independent Research and Development
IRR	Internal Rate of Return
Isp	Specific Impulse
IU	Interface Unit
IUS	Inertial Upper Stage
JSC	Johnson Space Center
K	Thousand
KEW	Kinetic Energy Weapon
KSC	Kennedy Space Center
KW	Kilowatt
LAN	Local Area Network
LBS	pounds
LCA	Launch Control Amplifier
LCC	Life Cycle Cost
LCCV	Low Cost Cargo Vehicle (MMC)
LCE	Low Cost Expendable
LCEP	Low Cost Expendable Propulsion
LC-Titan	Large Core Titan
LDC	Large Diameter Core
LEM	Lunar Excursion Module
LES	Launch Escape System
LEO	Low Earth Orbit
LH	Left Hand
LH2,LH2	Liquid Hydrogen
Li-$SOCl_2$	Lithium Sulphur Oxygen Chlorine
Li	Lithium
LN_2	Liquid Nitrogen
LO2,LO_2	Liquid Oxygen

ACRONYMS and ABBREVIATIONS
(Continued)

LPS	Launch Processing System
LRBs	Liquid Rocket Boosters
LRE	Liquid Rocket Engine
LRU	Line Replaceable Unit
LSC	Linear Shaped Charge
LV	Launch Vehicle
L&L	Launch and Landing
M	Million
MC	Mission Control
MCC	Main Combustion Chamber
MCR	Modification Change Request
MCS	Mission Control System
MCT	Mission Control Teams
MDAC	McDonnell Douglas Astronautics Company
MDM	Multiplex/De-multiplex
ME	Main Engine; Maintenance Expert
MELV	Medium Expendable Launch Vehicle
MEO	Medium Earth Orbit
MFRCV	Manned Fully Reusable Cargo Vehicle(s) (STS II)
MFRGB	Manned Fully Reusable Ground Based-OTV
MFRSB	Manned Fully Reusable Space Based-OTV
MILSTAR	Military Transmission and Relay Satellite
MLP	Mobile Launcher Platform
MMC	Martin Marietta Company
MMMA	Martin Marietta Michoud Aerospace
MMU	Manned Maneuvering Unit
MPM	Manipulator Positioning Mechanism
MPRCV	Manned Partially Reusable Cargo Vehicle
MPS	Main Propulsion System
MPSR	Multipurpose Support Room
MPST	Multipurpose Support Team
MSBLS	Microwave Scanning Beam Landing System
MSFC	Marshall Space Flight Center
MS/NAS	Machine Screw/National Aircraft Standard
MTBF	Mean-Time Between Failure
MTTR	Mean-Time to Repair
NaS	Sodium Sulphur
NAS	National Airspace System
NA-S	National Aircraft Standard
NASA	National Aeronautics and Space Administration
NASA/RECON	Remote Console (NASA information retrieval system)
NCCS	Network Communication and Control Stations
NCS	Network Control Stations
NDE	Non-Destructive Evaluation
NDT	Non-Destructive Test
Ni-Cd	Nickel-Cadmium
NiCad	Nickel Cadmium
NIH	Not Invented Here
$Ni\text{-}H_2$	Nickel-Hydrogen
NiTi	Nickel-Titanium
Nitinol	Nickel-Titanium-Naval Ordnance Laboratory
NLG	Nose Landing Gear
NORAD	North American Air Defense
NSI	NASA Standard Initiator
N_2H_4	Hydrazine Monopropellant
N_2O_4	Nitrogen Tetroxide

ACRONYMS and ABBREVIATIONS
(Continued)

OAA	Orbiter Access Arm
OBECO	Outboard Engine Cutoff
O&M	Operations and Maintenance
OMI	Operations and Maintenance Instruction
OMP	Operationsand Maintenance Plan
OMRSD	Operational Maintenance Requirements and Specifications Document
OMS	Orbital Maneuvering System
OMV	Orbital Maneuvering Vehicle
OPC	Operations Planning Center
OPF	Orbiter Processing Facility
OPS	Operations
ORB	Orbiter
ORU	Orbiter Replacement Unit; Orbital Repaired Unit
OTV	Oribital Transfer Vehicle
OV	Orbiter Vehicle
P/A	Propulsion/Avionics Module
PAM	Payload Assist Module; Payload Applications Module
PAREC	P/A Recovery Area
PC	Printed Circuit
PCBS	Printed Circuit Boards
PCP	Power Control Panel
PCR	Payload Changeout Room
PDI	Payload Data Interleaver
PDR	Preliminary Design Review
PFLB	Pressure Fed Liquid Booster
P/FRCV	Partially/Fully Reusable Cargo Vehicle
PGHM	Payload Ground Handling Mechanism
PGOC	Payload Ground Operations Contractor (MDAC)
PIC	Pyro Initiator Controller
PIDB	Preliminary Issues Database
PL, P/L	Payload
PLB	Payload Bay
PLF	Payload Fairing or Payload Facility
POCC	Payload Operations Control Center
POI	Product of Inertia
PR	Problem Report
PRCBD	Program Review Control Board Directive
PRSD	Power Reactant Storage and Distribution
PSA	Payload Support Avionics
PSI	Pounds Per Square Inch
PSP	Processing Support Plan
PV	Present Value
PV&D	Purge, Vent and Drain
QA	Quality Assurance
QC	Quality Control
QD	Quick Disconnect
RADC	Rome Air Development Center
RAMCAD	Reliability and Maintainability through Computer Aided Design
RCC	Reinforced Carbon Carbon
RCS	Reaction Control System
R&D	Research and Development
RECON	Remote Console (NASA information retrieval system)
RF	Radio Frequency
RFCS	Regenerative Fuel Cell System
RFP	Request for Proposal

ACRONYMS and ABBREVIATIONS
(Continued)

RH	Right Hand
RIC	Rockwell International Corporation
RJDA	Reaction Jet Drawer
RMS	Remote Manipulator System
R&PM	Research and Program Management
RPSF	Remote Processing and Storage Facility(s)
RP-1	Rocket propellant-JP-X based
R/R,R&R	Repair/Replace
RSI	Reusable Surface Insulation
RTOMI	Repetitive Task Operations and Maintenance Instruction
RTS	Remote Tracking System
RTV	Room Temperature Vulcanizing
R&T	Research and Technology
RU	Remote Unit
S	Sulphur
SAFT	Semi-Automatic Flight Line Tester
SAT	Satellite
S&A	Safe and Arm
SB	Space Based
SBS	Space Based System
SBSS	Space Based Space Surveillance (System)
S/C	Spacecraft
SCAPE	Self-Contained Atmospheric Protective Ensemble
SDI	Space Defense Initiative
SDIO	Space Defense Initiative Office/Organization
SDV	Shuttle Derived Vehicle
SiC	Silicon Carbine
SIP	Standard Interface Panel; Strain Isolation Pad
SIT	System Integrated Test
SLSOC	Simplified Launch System Operational Criteria
SM	Support Module
SMA	Shape-Memory Alloy
SMCH	Standard Mission Cable Harness
SME	Shape Memory Effect
SOA	State-of-Art
SOC	Satellite Operations Center
SOPC	Shuttle Operations Planning Center
SOW	Statement of Work
SPACECOM	Space Command
SPADOC	Space Defense Operations Center
SPC	Shuttle Processing Contractor (Lockheed)
SPIDPO	Shuttle Payload Integration and Development Program Office (JSC)
SPDMS	Shuttle Processing Data Management System
SPI	Standard Practice Instructions
SRB, SRBs	Solid Rocket Booster(s)
SRM, SRMs	Solid Rocket Motor(s)
SRSS	Shuttle Range Safety System
SS	Space Station
SSME	Space Shuttle Main Engine(s)
SSMEC	Space Shuttle Main Engine Controller
SSSF	SRB Segment Storage Facility
SSTO	Single Stage to Orbit
ST	Space Telescope
STA,STAS	Space Transportation Architecture (Study)
STC	Satellite Test Center
STE	Systems Test and Evaluation or Special Test Equipment
STS	Space Transportation System; Shuttle Transportation System

ACRONYMS and ABBREVIATIONS
(Continued)

STS II	Space Transportation System II
SV	Space Vehicle
S\W,(SW)	Software
T-III	Titan III
TACAN	Tactical Navigation
TARS	Turnaround and Reconfiguration Simulation
TAV	Transatmospheric Vehicle
TBD	To be Determined/Defined
T&C/O	Test and Checkout
TDAS	Tracking and Data Acquisition Satellite
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
TE	Test Equipment
Tempest	Electromagnetic emission suppression for security purposes
TIS	Technology Identification Sheet
TM	Telemetry
TP	Test Point; Test Plan
T-0	Liftoff Time
TOs	Transfer Orbit Stage
TPS	Thermal Protection System; Test Preparation Test
TRAJ	Trajectory
TS	Transportation System
T/S	Test Setup
TSM	Tail Service Mast
T&CN	Telemetry & Communication Network
TTL	Transistor/Transistor Logic
TVC	Thrust Vector Control
UART	Universal Asynchonous Transistor
UDMH	Unsymmetrical Dimethylhydrazine
UDS	Universal Documentation System
UEXCV	Unmanned Expendable Cargo Vehicle
UFRCV	Unmanned Fully Reusable Cargo Vehicle
UFRGB	Unmanned Fully Reusable Ground Based-OTV
UFRSB	Unmanned Fully Reusable Space Based-OTV
UHF	Ultra High Frequency
ULCE	Unified Life Cycle Engineering
ULV	Unmanned Launch Vehicle
UPRCV	Unmanned Partially Reusable Cargo Vehicle(s)
UPRCV(R)	Unmanned Partially Reusable Cargo Vehicle with Return
UPXCV	Unmanned Partially Expendable Cargo Vehicle
UMB	Umbilical
VAB	Vehicle Assembly Building
VAFB	Vandenberg Air Force Base
VC1	Visual Clean 1 (standard)
VC1A	Visual Clean 1A (sensitive)
VC2	Visual Clean 2 (highly sensitive)
VHF	Very High Frequency
VHMS	Vehicle Health Monitoring System
VHSIC	Very High Speed Integrated Circuit
VIB	Vertical Integration Building
VIF	Vertical Integration Facility
VLSI	Very Large Scale Integration
VPF	Vertical Processing Facility

ACRONYMS and ABBREVIATIONS
(Continued)

WAD	Work Authorization Document
WBS	Work Breakdown Structure
WEM	Water Electrolysis Module
WCCS	Window Cavity Conditioning System
WSMC	Western Space and Missile Center
WCS	Waste Conditioning System
WSB	Water Spray Boiler
WTR	Western Test Range
XTKB	Expanded Technology Knowledge Base

1.0 INTRODUCTION

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CIRCA 2000 -- OPERATIONS REQUIREMENTS FOR AN ORBITAL ACCESS SYSTEM

1.0 INTRODUCTION

BACKGROUND: STS ground operations were evaluated in the KSC Shuttle Ground Operations Efficiencies / Technologies (SGOE/T) Study performed by Boeing. This Study has identified the high-cost, hazardous, time and manpower consuming problem areas involving vehicles, facilities, test & checkout, system engineering, and management systems. Elimination or drastic reduction of these cost driver systems will significantly reduce the recurring costs of prelaunch processing and launch operations for space vehicles. The Circa 2000 operations requirements were developed using STS as a working data source.

OBJECTIVE: The objective of the CIRCA 2000 system is to identify operations that, if corrected, will drive overall life cycle costs down drastically. Once identified, the responsible program design teams can correct or provide alternate design solutions so that overall life cycle costs can be driven down by an order of magnitude compared to the current STS system.

APPROACH: The approach is to develop individual operational requisites for: (1) the associated management and system engineering; (2) the test & checkout techniques; (3) the orbital access vehicle; and (4) the supporting facilities. CIRCA 2000 System, Figure 1, lists the essential elements of each design category and names the operations requirements for each element. Backup sheets provide expansion of these requirements. This expansion includes the associated rationale, sample concepts, identification of technology developments needed, technology references and abstracts.

The next step in this document is demonstrate the feasibility of the operational requirements by developing a radical, but potentially workable, concept which includes an example vehicle and its related ground operations including a headcount and facility analysis.

The final step will be for the designers to satisfy the operations requirements in a way that will reduce the operations life cycle costs by a factor of ten compared to Shuttle. Keep in mind that past trade studies are no longer valid; technology changes daily and old trades were done with inaccurate estimates of operations costs.

GOALS: All of us have prejudices, based on our individual experiences over the years, as to what will or will not work. Uncontrolled growth, based on those experiences, is a major reason why our current Life Cycle Costs (LCC) have become exorbitant. Vehicle design has been performance oriented. Operations methods/techniques have been based on vehicle design which was in turn, based on vehicle performance. Designers have had no previous hard requirement and therefore, little or no incentive to design vehicles based on LCC -- that is, until NOW.

In the final analysis, all designs are compromises. We have outlined the operations cost drivers and have proposed at least one concept for each cost driver that, when integrated, generate an order of magnitude cost reduction. It is the intent of these concepts to stimulate the thinking of the design teams best qualified to improve or replace conventional design approaches with these sample concepts and, from them, develop simple working systems that will meet or beat LCC reduction objectives. Those companies/organizations that use innovative approaches to solve these problems will be the Aerospace companies still around in the post-2000 era. The Countries that pursue these solutions will be the Leaders in Space.

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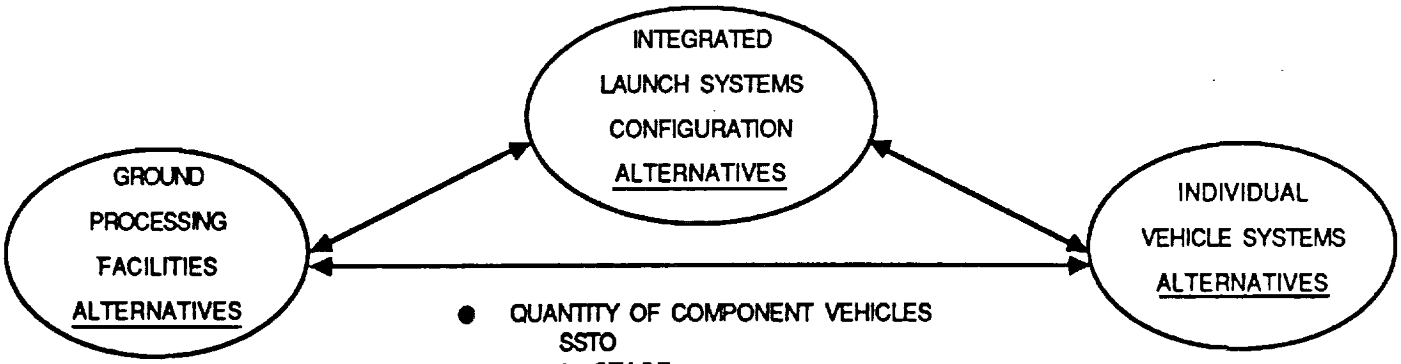
CIRCA 2000 SYSTEM
INTERRELATED ALTERNATIVES
(Vertical Launch Assumed)



- VEHICLE PROCESSING MODE
  - VERTICAL
  - HORIZONTAL
  - COMBINATION
- PAYLOAD PROCESSING MODE
  - VERTICAL
  - HORIZONTAL
  - COMBINATION
- P / L INTEGRATION
  - OPF ONLY
  - VAB ONLY
  - PAD ONLY
  - COMBINATION
- VEHICLE MATE
  - HORIZONTAL
  - VERTICAL
- ERECTION
  - VAB
  - PAD
- VEHICLE ACCESS
  - ALL LOCATIONS
  - OPF ONLY
  - COMBINATION
- TRANSFER TO PAD
  - ML / CT
  - BARGE
  - LANDING GEAR
  - ERECTOR / TRANSPORTER
  - RAIL
- PAD SYSTEMS

- QUANTITY OF COMPONENT VEHICLES
  - SSTO
  - 2 - STAGE
  - 3 - STAGE
- COMPONENT VEHICLE MATING
  - STACK
  - PARALLEL
  - COMBINATION
- FUEL
  - SINGLE
  - MULTIPLE
- RECOVERABLE
  - ALL
  - PART
- LANDING
  - HORIZONTAL
  - VERTICAL
- MANNED
  - FLIGHT CREW
  - PASSENGER MODULE ONLY

THE UNAVOIDABLE INTERRELATIONSHIPS OF GROSS VEHICLE CONFIGURATION, VEHICLE SYSTEMS, AND GROUND SUPPORT PROCESSING ARE INDICATED. PRELIMINARY DESIGN MUST ACCOMMODATE EXPERIENCED PERSONNEL FROM ALL THREE TO MINIMIZE LCC

- PROPELLANTS
  - LOX
  - RP-1
  - LH2
  - CH4
  - C3H8
  - SOLIDS
  - HYPERGOLS
- ON - BOARD POWER
  - FUEL CELLS
  - BATTERIES
  - COMBINATIONS
  - HYDRAULIC SUPPLY
    - APU
    - MPS
- PNEUMATICS
  - PURGE
  - TANK PRES.
  - VALVE CONTROL
- TEST - & - C / O
  - MANUAL
  - AUTOMATIC
  - AUTONOMOUS
  - INTEGRATED

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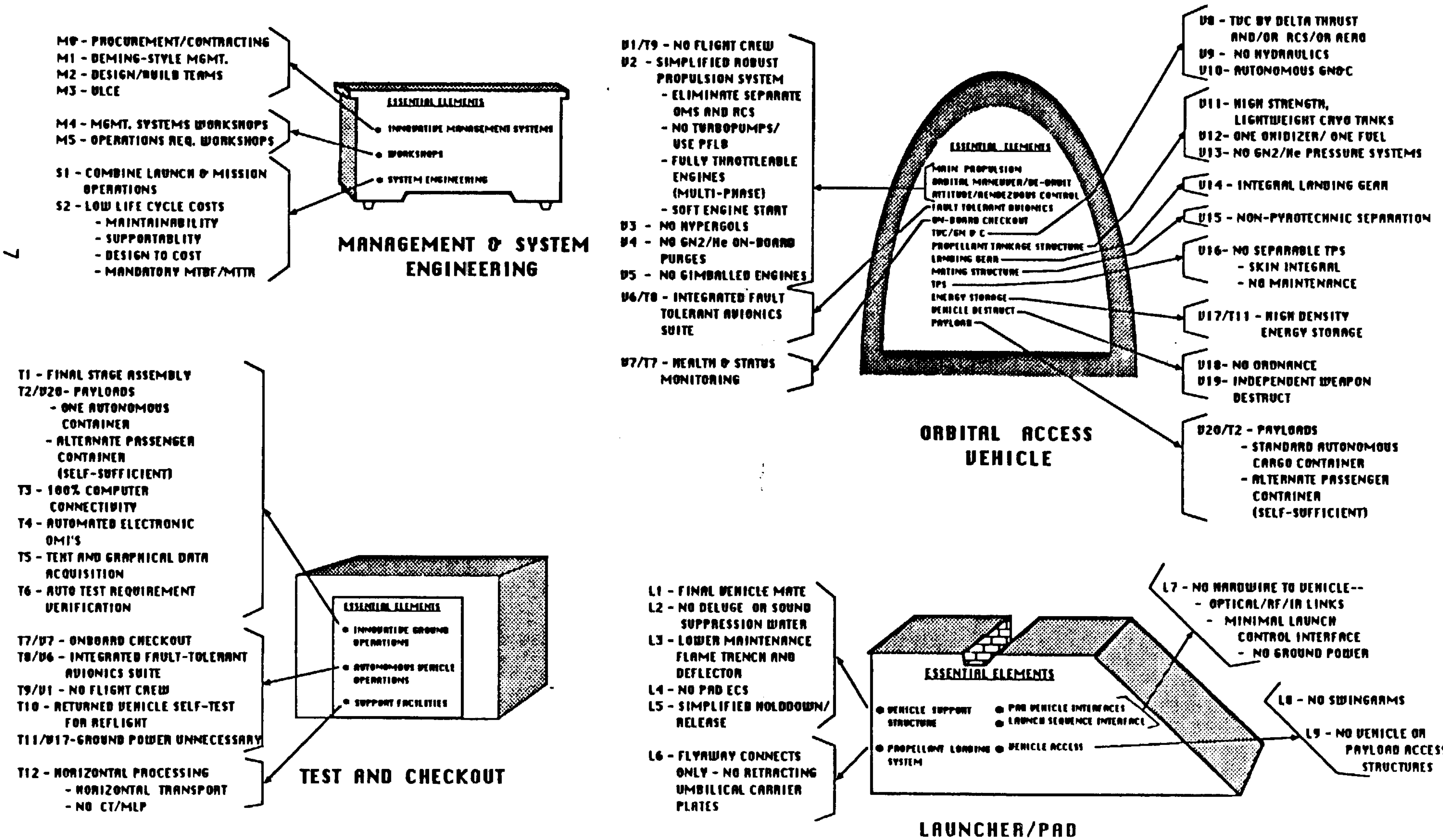
CIRCA 2000 SYSTEM
OPERATIONAL REQUIREMENTS



CIRCA 2000 SYSTEM
OPERATIONAL REQUIREMENTS

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2.0 CIRCA 2000 OPERATIONS REQUIREMENTS

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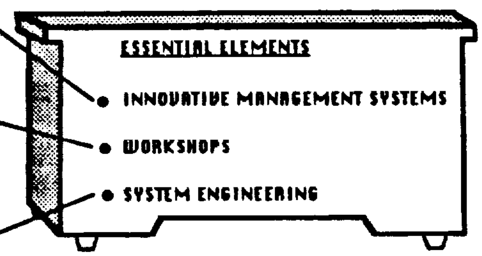
MØ - PROCUREMENT/CONTRACTING
M1 - DEMING-STYLE MGMT.
M2 - DESIGN/BUILD TEAMS
M3 - ULCE

M4 - MGMT. SYSTEMS WORKSHOPS
M5 - OPERATIONS REQ. WORKSHOPS

S1 - COMBINE LAUNCH & MISSION OPERATIONS
S2 - LOW LIFE CYCLE COSTS
- MAINTAINABILITY
- SUPPORTABLITY
- DESIGN TO COST
- MANDATORY MTBF/MTTR



MANAGEMENT & SYSTEM ENGINEERING

CIRCA 2000 SYSTEM OPERATIONAL REQUIREMENTS

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CIRCA 2000 REQUIREMENT DATA

Essential Element: INNOVATIVE MANAGEMENT SYSTEMS

No:MO **Title:** Procurement / Contracting

Operations Requirement:

Government procurement must utilize a contracting mode that establishes prime contractors with sufficient system integration authority to define system (hardware and software) configuration requirements. This will enable cost-effective management for the total system architecture (including hardware acceptance and sub-contractor control).

Rationale:

Contracts that specify GFE, such as engines, and dictate detailed specifications rather than end product performance severely limit a prime contractor's ability to achieve the optimum design or manage the job in a cost effective manner. Most detail hardware specifications limit the contractor's capability to be innovative and cost effective.

Sample Concept:

Program level specifications should be developed only for the top level of end product performance and include profit incentives.

Production contracts for systems / components should be placed under control of the prime contractor.

FOR EXAMPLE: The lunar orbiter program was a highly successful performance incentive program that operated under this concept.

Technology References:

SGOE/T Study Report, "SOCH Appendices", Draft dated 9/8/87.

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Essential Element: INNOVATIVE MANAGEMENT SYSTEMS

No: M1 **Title:** Deming Style Management

Operations Requirement:

Traditional compartmented management style must be replaced with Deming-type, team-style management with integrated quality.

Rationale:

In maturing over the past twenty-five years, aerospace management, both in and out of government, have succumbed to bureaucratic disease whereby the first consideration of any management or technical problem is how it will affect the "status quo". If the effect is negative in any way, the answers are often skewed preventing top management from making cost effective decisions. Top management also suffers from biased decisions made to accommodate their "status quo".

Sample Concept:

Computerized databases can eliminate need for many middle managers who now only gather and provide information for top management decisions. This will allow top managers who know how to effectively use computer tools to obtain data that is unfiltered and unbiased by middle management protecting their turf.

Management culture must change to a more participative management style (a la Deming) without wasteful department barriers. This must take place both in NASA and contractor ranks.

With a high percentage of managers in NASA and contractors approaching retirement, there is an unusual opportunity to accomplish the change. Care must be taken not to replace these retiring managers with their look-alike proteges or nothing will be gained. Selection of new managers should be based on their ability to make imaginative use of the latest management technology and who are not ingrained with parochial viewpoints.

The individual program objectives should determine the organization requirement -- not vice-versa.

Technology Requirement:

A total culture change in managerial techniques. Brain restructuring.

Technology References:

"Managing Quality" Handbook, Boeing Aerospace Co., September '85

"The Deming Route to Quality and Productivity", W.W. Scherkenbach 1986.

SGOE/T Study Report, "SOCH Appendices", Draft dated 9/8/87.

Essential Element: INNOVATIVE MANAGEMENT SYSTEMS

No:M2 **Title:** Design/Build Teams

Operations Requirement:

Beginning with the conceptual definition through the design phase, integrate the experience and knowledge of specialists in all areas, including manufacturing, procurement, ground operations, etc.

Rationale:

As a result of compartmentalized organization responsibilities, past vehicle designs have not fully utilized and integrated the knowledge and experience of specialists in all functional organizations.

The past sequence of hardware development, whereby the hardware designer completes his design (without input from manufacturing, purchasing, operations, etc.) and "throws it over the fence", for the other organizations to do the best they can in producing and operating the hardware in a cost-effective way, has led to life cycle cost an order-of-magnitude higher than necessary.

Sample Concept:

Management must adopt design/build team concepts. This will provide an adequate flow of experience and coordination from operational elements to engineering design during the definition and development stage.

Individual program requirements should determine its organizational structure -- not vice-versa.

Technology Requirement:

Advanced teamwork.

Technology References:

SGOE/T Study Report, "SOCH Appendices", Draft dated 9/8/87.

SGOE/T Study Phase 1 Final Report, Volume 1, pp.14-16, dated 5/4/87.

CIRCA 2000 REQUIREMENT DATA

Essential Element: INNOVATIVE MANAGEMENT SYSTEMS

No: M3 Title: ULCE (Unified Life Cycle Engineering)

Operations Requirement:

Use Unified Life Cycle Engineering (ULCE). This is a design engineering environment in which computer-aided design technology is used to continually assess and improve the quality of a product during the active design phases as well as throughout its entire life cycle. This is accomplished by integrating and optimizing design attributes for producibility and supportability with design attributes for performance, operability, cost, and schedule.

Rationale:

No common database interchange structure exists for design criteria, design data, manufacturing data, reliability data, QA data trails and closeout, operations and maintenance procedures, or requirements satisfaction. This has led to gross duplication, omissions, inefficiencies, and, in some cases, errors.

Sample Concept:

Implement Unified Life Cycle Engineering (ULCE) system to provide birth-to-death unified data interchange, and enforce total use of MIL-STD-1840A throughout all system development and operational phases.

Provide for computerized approval/concurrence control of requirements, procedures, and anomaly close-outs as part of ULCE; also provide for risk management, configuration control, mission/range support, flight readiness reviews, resolution of in-flight anomalies. etc.

Technology Requirement:

Continued development of ULCE.

Technology References:

SGOE/T Study Report, "SOCH Appendices", Draft dated 9/8/87.

Essential Element: WORKSHOPS

No: M4 **Title:** Management System Workshops

Operations Requirement:

Develop and present workshops/seminars for Circa 2000 program management to introduce the required management culture change.

Rationale:

(See M1)

Sample Concept:

(See M1)

Technology Requirement:

(See M1)

Technology References:

Workshops to be scheduled during Phase 3 of this SGOE/T Study (after April '88).

Essential Element: WORKSHOPS

No:M5   **Title:** Operations Requirements Workshops

Operations Requirement:

Develop workshops/seminars for designers to further brainstorm implementation of the Circa 2000 operations requirements for an orbital access system.

Rationale:

These workshops would provide an advance interchange of ideas between operations and designers so that the best of both are integrated into the conceptual design of the circa 2000 system.

Sample Concept:

A series of design discipline workshops aimed at interchange of ideas to accomplish an order-of-magnitude reduction in life cycle costs for the Circa 2000 systems.

Technology Requirement:

None.

Technology References:

Workshops to be scheduled during Phase 3 of this SGOE/T Study (after April '88).

C I R C A   2 0 0 0   R E Q U I R E M E N T   D A T A

Essential Element: SYSTEM ENGINEERING

No: S1   **Title:** Combine Launch and Mission Operations

Operations Requirement:

Combine mission and launch operations.

Rationale:

There is much duplication in skills and manpower in the mission and launch operations functions.

Sample Concept:

Combine mission and launch operations functions at launch site.

Cost trade, even over long-term, may be negative because of real property investment at JSC (in addition to political implications).

Requirement:

Trade analysis on basis of costs rather than politics.

References:

STAS Reports, (Boeing, GDA, MMC, RI).

C I R C A 2 0 0 0 R E Q U I R E M E N T D A T A

Essential Element: SYSTEM ENGINEERING

No: S2 **Title:** Low Life Cycle Costs

Operations Requirement:

Operations efficiency must be considered during concept development and design.

Rationale:

Operations requirements have been disregarded in the past because they are brought up too late in the design cycle to be implemented in a cost-effective manner.

FOR EXAMPLE (FY-85 OPERATIONS COSTS FOR 8 FLIGHTS):

SRB	$464.2M	FLIGHT OPS	$345.3M
ET	415.8M	ORBITER HDWRE	162.6M
LAUNCH OPS	347.5M	CREW EQUIP	36.3M
PROPELLANTS	30.3M	SSME	51.6M
GSE	24.1M	CONTRACT ADMIN	17.1M

SUBTOTAL		$1894.8M
PLUS	NETWORK SUPPORT	$ 20.4M
	R & PM	274.2M
FY-85 TOTAL COST		$2189.4M (in '85 dollars for 8 flights)
	or	$ 273.5M per flight

Minimizing upfront program costs multiplies Life Cycle Cost.

Sample Concept:

Do not sacrifice operational efficiency for vehicle performance.
Build a truck - not a Ferrari.

Prepare thorough and realistic life cycle cost analysis for Congress.
Emphasize Life Cycle Cost - not start-up costs.

Implement tools listed below.

Technology Requirement:

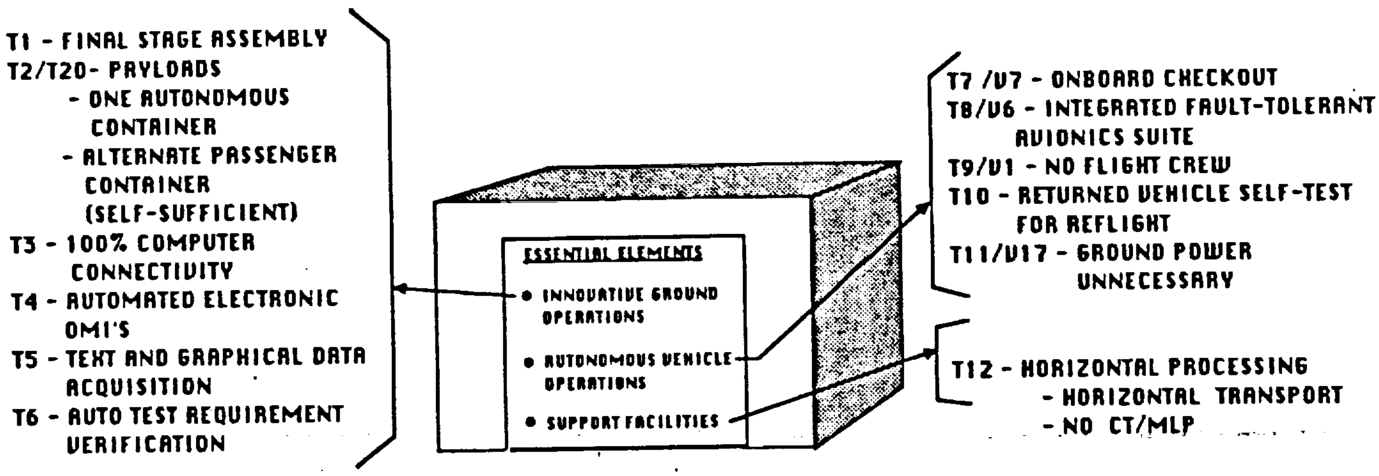
No new technology required, only further development and implementation of the proper concepts and tools:

- DEMING MANAGEMENT AND QUALITY TECHNIQUE
- ULCE
- DESIGN/BUILD TEAMS
- MAINTAINABILITY
- SUPPORTABILITY
- DESIGN-TO-COST
- MANDATORY MTBF/MTTR

Technology References:

86X75319	86X75294	86N28011	86A42620	86A42618	86A32095	86A30550	86A21872
85X70467	85N16743	85A45150	85A42678	85A26795	84X78919	84X74889	84X70100
84N26692	84N24495	84N23330	84N23150	84N23136	84N19129	84A30608	84A15212
84A15215	83A49586	83A49578	83A48334	83A43748	82A19787	81N29023	81N23354
81N11907							

Test and Checkout



TEST AND CHECKOUT

CIRCA 2000 SYSTEM OPERATIONAL REQUIREMENTS

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Essential Element: INNOVATIVE GROUND OPERATIONS

No: T1 **Title:** Final Stage Assembly

Operations Requirement:

Perform all stage assembly, refurbishment and T&C/O in one facility; including horizontal installation of autonomous payload.

Rationale:

Simplifies and minimizes assembly and T&C/O facilities. Eliminates a separate vehicle assembly building and large overhead lift-to-mate GSE.

(See also Item L1).

Sample Concept:

Reduce launch support facilities to three major categories:
1. Vehicle Assembly, T&C/O
2. Payload preparation
3. Launcher/pad

(See also Item L1)

Technology Requirement:

None.

Technology References:

This document, Section 3.0.

Essential Element: INNOVATIVE GROUND OPERATIONS

No: T2/V20 **Title:** Payloads - One Autonomous Container; Alternate Passenger Container (self-sufficient)

Operations Requirement:

Eliminate integrated vehicle/payload test and checkout.

Rationale:

Integrated T&C/O is very time consuming, requires expensive GSE, and is directly related to time and effort expended in reconfiguring the orbiter payload bay and vehicle support software. Autonomous payloads mounted within a standard vehicle configuration can dramatically decrease these related costs.

(See related Item V15).

Sample Concept:

Develop a payload bay module consisting of orbiter payload universal strongback and environmental cover (as needed) that has internal capability to support payload electrical, environmental, and communications requirements from loading until orbital placement. This philosophy is also applicable to man-carrying orbital-delivery module. Payloads can be tested and prepared for flight in the off-line payload facilities with no direct impact on fleet operations. Under the concept of autonomous payload modules with payload bay-universal pallets, the payload is rolled out to meet the flight-ready vehicle, loaded horizontally at the OPF, rolled to pad, erected, vehicle fueled, and launched. Payload integration within the autonomous container is the responsibility of the payload community.

Technology Requirement:

None, other than high-density power cells or other energy storage device to allow payload autonomy for one to three days during launch processing.

Technology References:

This document, Section 3.0.

C I R C A   2 0 0 0   R E Q U I R E M E N T   D A T A

Essential Element: INNOVATIVE GROUND OPERATIONS

No:T3 **Title:** 100% Computer Connectivity

Operations Requirement:

All computers associated in any manner with operations flight or ground must maintain complete connecting (bridging).

Rationale:

The vast amount of data required to support and maintain any operational system requires that the maximum efficiency in operations be always maintained. Paperwork currently requires a large portion of the allocated operation budget. A potential reduction of 5% of the total LCC can be achieved by automation of paperwork.

Sample Concept:

Utilization of commercial DBMS which support SQL (standard query language) and data import and export via MIL-STD-1840A.

Technology Requirement:

Distributed data base management systems providing for flexible computer connectivity.

Technology References:

NASA/RECON: 86N27948, 84N31144, 84N23296, 84N21107

DIALOG: 2034798, 2011582, 2011580, 1979702, 1978939, 1964804, 1947009, 1877817, 1876159, 1868213, 1852081, 1842967, 1836336, 1823013, 1380555

Essential Element: INNOVATIVE GROUND OPERATIONS

No: T4 **Title:** Automated Electronic OMI's

Operations Requirement:

Operational and support procedures should be computer-based and maintained.

Rationale:

Conventional hard copy procedures are difficult and expensive to maintain. the manual update, copy and distribution of procedures does not provide for efficient operations. The lack of procedural discipline results in many errors. Automated procedures would control procedural sequence, data recording and associated support data presentation.

Sample Concept:

Procedures to be received from vendor in MIL-STD-1840A including graphics. These data then to be processed into an operational site procedure format. As procedures are scheduled for performance, the test conductor calls them up on his terminal and follows display of instructions and sequences.

Technology Requirement:

Procedure authoring and update, standardize text and graphics formats.

Technology References:

NASA/RECON: 86N21206, 86N20477, 85N27754, 85N27121, 85N24835, 85N12793, 85N11603, 85A37968, 84N21406

DIALOG: 2037337, 2008924, 1783653, 1713486, 1670611, 1593032, 1502409, 1381439, 1335059, 1401285, 1221478

Essential Element: INNOVATIVE GROUND OPERATIONS

No:T5 **Title:** Text and Graphical Data Acquisition

Operations Requirement:

Import and export of text and graphics requires that data formats be standardized.

Rationale:

The large volume of operations and support data is currently generated, maintained, and distributed in hard copy form and is highly labor intensive.

Sample Concept:

Text and graphics data imported and exported via MIL-STD-1840A.

Technology Requirement:

Text and graphics standards: MIL-STD-1840A

Technology References:

NASA/RECON:	86N17218, 84N24236
DIALOG:	2037208, 2027585

Essential Element: INNOVATIVE GROUND OPERATIONS

No: T6 **Title:** Automatic Test Requirements Verification

Operations Requirement:

Test requirements verification must be automatically correlated with the completion of the associated procedures.

Rationale:

Current manual method is inefficient, inadequate, and error prone.

Sample Concept:

An automated OMI is truly paperless, with sequence execution controlled by the scheduling systems and should track the completion of each procedure and task. As each task is completed, without error, or retest accomplished, all associated test requirements are automatically verified.

Technology Requirement:

Distributed data processing, networking, computer/data connectivity.

Technology References:

NASA/RECON: 85N30000, 85A33722, 84N33290, 84A26738, 82N23042

C I R C A 2 0 0 0 R E Q U I R E M E N T D A T A

Essential Element: AUTONOMOUS VEHICLE OPERATIONS

No:T7/V7 **Title:** Onboard Checkout

Operations Requirement:

Current configurations require extensive use of GSE to support vehicle checkout. Future systems should incorporate onboard checkout and minimize GSE.

Rationale:

Current configurations require complex GSE hookups to support system test and operational verification. The configuration verification, required for test hookup and calibration, defeats efficient operations. Commercial aircraft provide 100% onboard checkout.

Sample Concept:

After a firm set of test requirements has been defined, early in the design phase, the associated hardware/software required to support on-board testing must be incorporated in each subsystem. It is important to maintain subsystem self-test autonomy.

Technology Requirement:

Bit and Integrated Fault Tolerant Avionics Suite (IFTAS) with layered architecture.

Technology References:

NASA/RECON: 87N10079, 87A33872, 86N20489, 86A23765, 85N16753, 85N16897, 85N16898, 85N16900, 85A24795, 85A28633, 85N34596, 85A45398, 84N14754, 84N26573, 84N34500, 84A46661, 83A45473

Essential Element: AUTONOMOUS VEHICLE OPERATIONS

No:T8/V6 **Title:** Integrated Fault Tolerant Avionics Suite (IFTAS)

Operations Requirement:

Avionics systems must provide for higher reliability by providing levels of fault tolerance in support of mandated system availability.

Rationale:

To support onboard checkout and mission success the entire avionics suite must be designed to provide that level of fault tolerance required to assure that the system is available when required. This is best accomplished by assuring the robustness of all mission critical systems, and providing fault tolerance where it is required (similar to a minimum equipment list for dispatch of commercial aircraft).

Sample Concept:

Future systems must be designed such that systems in general can be dynamically configured to provide for more than one function. Should an allocated processor or sub-system fail, another processor with a lesser priority function should be assigned to reconfigure and perform the function of the failed processor. This forces a high degree of commonality, and distributed processing.

Technology Requirement:

Distributed processing, layered architectures, commonality.

Technology References:

NASA/RECON: 86N20475, 86N20472, 86N20402, 86A47511, 86A47442, 86A37043, 86A33194, 86A28062, 86A11452, 85X10244, 85N30643, 85N23337, 85N16896, 85N16752, 85N11610, 85N10711, 85A44565, 85A43489, 85A34179, 85A24795, 85A17876, 85A17344, 84A43946, 84A41699, 84A26771, 84A26768, 84A10052, 84A10001, 83N36337

C I R C A 2 0 0 0 R E Q U I R E M E N T D A T A

Essential Element: AUTONOMOUS VEHICLE OPERATIONS

No: T9/V1 **Title:** No Flight Crew

Operations Requirement:

Design launch vehicle to be auto-piloted via on-board GN&C. Orbital maneuvering and rendevous remotely controlled from ground and/or Space Station/terminal destination.

Rationale:

Flight crew life support and manual control systems are very expensive, add weight, and are a major time-consumer during test and checkout. Manual control systems are not amenable to computerized, remote T & C/O or bit/bite. A large percentage of flights are for cargo only. Flight crew is not mandatory for a "taxi" function. Passengers to orbit are considered payload.

Sample Concept:

The vast majority of earth satellites have been launched to orbit with payloads released and placed in LEO or GEO without the aid of on-board personnel. The STS orbiter already has much of the capability needed for auto-trajectory and de-orbit/land capability.

Technology Requirement:

No new technology required, only development to meet specific requirements.

Technology References:

STAS Reports (unmanned vehicles): Boeing, GDA, MMC, RI

This document, Section 3.0.

Essential Element: AUTONOMOUS VEHICLE OPERATIONS

No:T10 **Title:** Returned Vehicle Self-test for Reflight

Operations Requirement:

After flight, returned vehicle should have sufficient self-test capability to verify flight readiness or problem isolation to LRU.

Rationale:

To accomplish order-of-magnitude cost reduction, we must achieve 160-Hr or better turnaround time. (160-Hrs was the original STS Turnaround goal whose actuals have grown an order-of-magnitude.)

Sample Concept:

During flight, bit identifies and records anomalies. After landing, bit/bite isolates problem to LRU level. After replacement, bit/bite retests and verifies flight readiness.

Technology Requirement:

Development of bit/bite to meet specific requirements.

Technology References:

NASA/RECON: 87N10079, 87A33872, 86N20489, 86A23765, 85N16753, 85N16897, 85N16898, 85N16900, 85A24795, 85A28633, 85N34596, 85A45398, 84N14754, 84N26573, 84N34500, 84A46661, 83A45473

Essential Element: AUTONOMOUS VEHICLE OPERATIONS

No:T11/V17 **Title:** Ground Power Unnecessary
(eliminate the requirement for ground power)

Operations Requirement:

Onboard power source capable of providing sufficient power for ground O&M, T&C/O, and launch operations without connection to facilities or GSE.

Rationale:

Ground power requirements with associated GSE and umbilicals complicate ground processing and require a supporting organization. This results in vehicle "power-up" being a costly repetitive milestone in STS processing. It should be routine such as 767, B-1, etc.

Sample Concept:

High density energy storage systems, such as regenerative fuel cells or sodium/sulphur batteries to provide on-board power. Fuel cells should be capable of using propellant grade H2 and O2.

Technology Requirement:

Accelerated development of energy storage systems with emphasis on fuel cells and sodium/sulphur batteries.

Technology References:

NASA/RECON: 87X70518, 87N22801, 87N19811, 87N19809, 87N17397, 87N16453, 87N14860, 87N12998, 87A33793, 87A33790, 87A33778, 87A33787, 87A15901, 87A14170, 86X73564, 86X73563, 86X72121, 86X71138, 86X70734, 86N28331, 86N28329, 86N27586, 86N23047, 86N17886, 86N16734, 86N16495, 86N14764, 86C12215, 86B10483, 86B10277, 86A37201, 86A36369, 86A24845, 85X76813, 85X72247, 85N71096, 85N33588, 85N16292, 85N31372, 85N13880, 85N13850, 85A45422, 85A33144, 85A26700, 85A26501, 85A12599, 84X75772, 84N31535, 84N12246, 84N10493, 84A30956, 84A30107, 84A30103, 83N14683, 81N22305, 81K10462, 80A20128, 75N24837

Essential Element: SUPPORT FACILITIES

No: T12 **Title:** Horizontal Processing
Horizontal Transport

Operations Requirement:

Provide combination of flight vehicle design and inter-related ground processing requirements and support facilities resulting in the simplest, least costly repetitive launch cycle. Horizontal mode proposed by this study.

GROUND PROCESSING MODE COMPARISON

Rationale

	VERTICAL	HORIZONTAL
TRANSPORTATION	- COMPLEX TRANSPORTER AND SELF-LEVELING PLATFORM - GREATER CLEARANCE REQUIREMENTS	+ VEHICLE SERVES AS TRANSPORTER
HANDLING	- REQUIRES EXTENSIVE USE OF HOISTS/CRANES/SLINGS AND STRONGBACKS - VEHICLE MUST PROVIDE MULTIPURPOSE ATTACH POINTS FOR ELEMENT ROTATION - FLIGHT VEHICLES "IN THE AIR" DURING ROTATION, LIFT, & MATE. PENDULUM EFFECT CREATES TEDIOUS & HAZARDOUS OPERATIONS.	+ INDIVIDUAL ELEMENT ROTATION NOT REQUIRED PRIOR TO INTEGRATION AT PAD + CONCEPT UTILIZES MOBILE CRANE WITH POWER-DOWN CONTROLS FOR ROTATION (SIMPLIFIED CAPITAL EQUIPMENT INVESTMENT AND O&M) + FLIGHT VEHICLES ALWAYS IN CONTACT WITH GROUND UNTIL LAUNCH
L.V. INTEGRATION	- COMPLEX MATE/DEMATE OPERATIONS	+ VEHICLE NESTING REDUCES HANDLING, SIMPLIFIED MATE/DEMATE
ROLLOUT	- VEHICLE STACKED ON LAUNCH PLATFORM WHICH MUST BE MOBILE AND SELF-LEVELING	+ ROLLOUT ON INTEGRAL LANDING GEAR - REQUIRES L.V. ERECTOR SYSTEM AT PAD
OPERATIONAL ACCESS (VEHICLE)	OPF: + SAME AS HORIZONTAL POST OPF: - CIRCUMFERENTIAL ACCESS - PROVIDES DIMINISHED CONTINUOUS VEHICLE ACCESS - INCREASES LOGISTICAL RESPONSE - USE OF ELEVATORS OR HOISTS/CRANES - INCREASES TECHNICIANS RESPONSE TIME - REQUIRES MULTIPLE ENTRY ACCESS KITS (VERT., HORIZ.) (MANUFACTURED HORIZ.) - GREATER NUMBER OF "HAZARDOUS AREA" CLEARS DUE TO OVERHEAD HOISTING	POST OPF: + LONGITUDINAL ACCESS - SUBSTANTIAL CONTINUOUS VEHICLE ACCESS + DECREASES LOGISTICAL RESPONSE + INCREASES OPERATIONS EFFICIENCY - UNIQUE VEHICLE ACCESS KITS REQUIRED + CONDUCIVE TO PARALLEL OPERATIONS
FACILITIES	- REQUIRES TALL STRUCTURES WITH ADEQUATE "BAY TO BAY" CLEARANCES - REQUIRES COMPLEX ACCESS PLATFORMS (EXTEND/RETRACT TYPE) - INCREASES O&M - REQUIRES MULTIPLE VEHICLE RELOCATIONS: RECEIPT, C/O AND STANDARD INTEGRATION - REQUIRES CRAWLERWAY OR EQUIV	+ BARREN PAD; CATASTROPHIC DAMAGE GREATLY MINIMIZED + SYNERGISTIC TO PRODUCTION PLANT LAYOUT & APPLICATION (COMMON HANDLING EQUIP.) + REDUCES NUMBER OF VEHICLE MOTIONS + LESSENS O&M + NO SEPARATE VEHICLE INTEGRATION FACILITY (VAB) NEEDED - REQUIRES TAXI-STRIP

T12 (Continued)

	VERTICAL	HORIZONTAL
PAYLOADS	+ CAPABLE OF HANDLING VERTICAL PAYLOADS + STS NON-DOD P/L's THRU STS-33 WERE: 80 HORIZONTAL 106 VERTICAL + HIGH ORBIT P/L's SAVE CRITICAL WEIGHT WITH VERTICAL PROCESSING + BETTER PAYLOAD ACCESS	- CANNOT HANDLE VERTICAL PAYLOADS + ANALYSIS OF NON-DOD STS P/L's TO-DATE SHOWS THE HORIZONTAL/VERTICAL RATIO COULD HAVE BEEN 149/37 FOR CIRCA 2000 INSTEAD OF THE 80/106 ACTUAL FOR STS - HIGH ORBIT P/L's REQUIRE INNOVATIVE HORIZONTAL SUPPORT + STAS GROUNDRULE G-6, "FOR NEW SYSTEMS, ASSUME NO PAYLOAD CHANGE-OUT AT THE PAD."

CONCLUSIONS:

- o Horizontal vehicle processing is more efficient
- o Vehicle must be self transporting (integral landing gear)

Sample Concept:

Horizontal T&C/O processing concept requires the following full-cycle ground operations description to demonstrate viability.

GROUND PROCESSING SEQUENCE

1. Flyback booster and glideback orbiter land at post-launch post-mission intervals at the SLF or equal.
2. Stages safed and towed on integral landing gear to deservice/ refurbish/launch preparation facilities (OPF or equal).
3. Download removed in horizontal attitude by overhead crane (OPF or equal).
4. Stages serviced and prepared for launch.
5. Autonomous payload canister/cocoon/pallet installed in orbiter in horizontal attitude in same facility (using same GSE as download), by overhead crane (OPF or equal).
6. Stages towed in horizontal attitude on integral landing gear to launch pad and rotated to vertical about the aft landing gear onto lift-off-style aft umbilical Q/D carriers, using specially selected mobile crane having state-of-the-art control systems and horizontal vehicle restraint winch. One stage towed-in from pad south ramp, second towed-in from pad north ramp. stages attached back-to-back. Alternate scenario for non-winged vehicle is further-simplified pad with single access route and all stages mated side-by-side. Technician access via special mobile access manlift. Stage max. length limited by mobile crane boom-length/load radius capability. 180-ft. approximate maximum stage length considered feasible state-of-art with existing KSC equipment.

T12 (Continued)

7. Launch

Technology Requirement:

1. Development of reusable moderate-size stages with integral landing gear or specially adapted dollies. Winged stages consistent with STAS 3rd phase recommendation.

2. Radically simplified, autonomous (self-test/evaluation; self-contained electrical power) stages.

3. Radically simplied, "barren pad".

4. Acceptance/development of mobile crane usage for flight hardware based on highly satisfactory operational history at KSC.

Technology References:

NASA/RECON: 86X76652, 85N16967, 85N16927, 85N12001, 85A13163, 85A12988, 84X74531, 84N75063, 84A44153, 83X71371, 83A31196, 81A26524, 80X72115

Essential Element: SUPPORT FACILITIES

No: T12.1 **Title:** Horizontal Transport of Stages to Pad (erection at pad)

Operations Requirement:

Eliminate LV rotation and high-lift VAB scenario and the related extensive GSE and GSO army.

Rationale:

Conventional rotation, lift, and mate in the VAB requires immense mobilization for complex, interrelated GSO, equipment, and personnel.

Sample Concept:

Perform T&C/O of all stages in horizontal attitude. Only one set and type of access GSE is required. Complete T&C/O, roll individual stages to pad on integral landing gear (reusable vehicle) or relatively simple dolly (for an expendable vehicle), rotate to vertical with mobile crane and install stage-mate fitting. Simplified vehicle and pad are key to reduced time at pad. Passenger access to the payload bay (passenger module) subsequent to propellant loading can be made by mobile vehicle, such as modified man-lift. If access for vertical payload insertion were made mandatory, it would cause the return of costly structures and O&M army and compromise the "barren-pad" concept.

Technology Requirement:

SIMPLIFIED LAUNCH VEHICLE AND GREATLY REVISED DESIGN AND OPERATIONS PHILOSOPHY AIMED AT ELIMINATING ALL POSSIBLE GSE AND GROUND SUPPORT OPERATIONS.

Proposed pad and vehicle are very much simplified from conventional concepts. Vehicle simplification, as proposed in other items herein, eliminates dependence on multi-level vehicle access/connections provided by swingarms.

Technology References:

This document, Section 3.0.

CIRCA 2000 REQUIREMENT DATA

Essential Element: SUPPORT FACILITIES

No:T12.2 **Title:** No Crawler Transporter / MLP

Operations Requirement:

Eliminate very large, heavy, very complex, O&M intensive mobile vehicles.

Rationale:

MLPs are required only for LVs of great size, weight, and awkward configuration that are not amenable to normal highway-type transport. If each stage is rolled to the pad on integral landing gear or relatively simple dollies, and rotated/mated at the pad, both MLPs and CTs are no longer required.

Sample Concept:

The year 2000 launch vehicle can have a fully reusable booster and orbiter (both having landing gear) or reusable flyback booster and expendable payload stage. The expendable payload stage would require a roadable dolly that would follow it continuously from receipt at KSC to the pad. Rotation via mobile crane at the pad would then provide the possibility of greatly simplified GSE and ground support operations.

(See also, T12.1)

Technology Requirement:

None

Technology References:

This document, Section 3.0.

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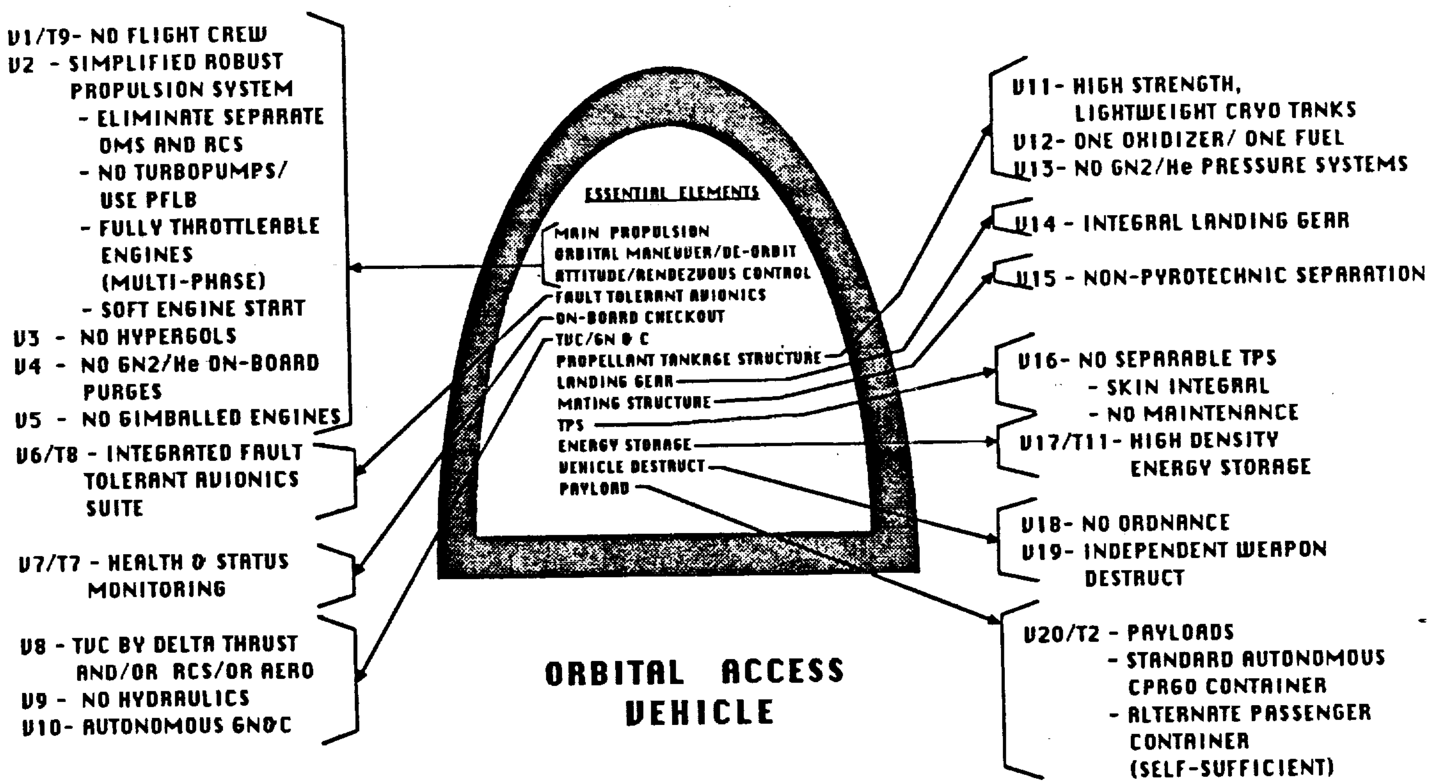
Orbital Access Vehicle



CIRCA 2000 SYSTEM OPERATIONAL REQUIREMENTS

Essential Element: MAIN PROPULSION

No: V1/T9 **Title:** No Flight Crew

Operations Requirement:

Design launch vehicle to be auto-piloted via on-board GN&C. Orbital maneuvering and rendezvous remotely controlled from ground and/or Space Station/terminal destination.

Rationale:

Flight crew life support and manual control systems are very expensive, create unnecessary added weight, and are a major source of time-consumption during test and checkout. Manual control systems are not amenable to computerized, remote T & C/O or bit/bite. A large percentage of flights are for cargo only. Flight crew is not mandatory for a "taxi" function. Passengers to orbit are considered payload.

Sample Concept:

The vast majority of earth satellites have been launched to orbit with payloads released and placed in LEO or GEO without the aid of on-board personnel. The STS orbiter already has much of the capability needed for auto-trajectory and de-orbit/land capability.

Technology Requirement:

No new technology required, only development to meet specific requirements.

Technology References:

STAS Reports: Boeing, GDA, MMC, RI

This document, Section 3.0.

Essential Element: MAIN PROPULSION

No: V2 **Title:** Simplified Robust Propulsion System

Operations Requirement:

Simplified, integrated, robust propulsion system that, using the same oxidizer and fuel, integrates the essential elements of main propulsion, orbital maneuver/de-orbit, and attitude/rendezvous control.

Rationale:

Current propulsion systems started with an engine design and the MPS built around it. There is a necessity to simplify and integrate all propulsion systems and radically minimize the supporting operations and maintenance.

Sample Concept:

Eliminate separate OMS and RCS	(see V2.1)
No turbopumps/use pressure-fed	(see V2.2)
Fully throttleable engines/multi-phase	(see V2.3)
Soft engine start	(see V2.4)

Technology Requirement:

(See V2.1, V2.2, V2.3, V2.4)

Technology References:

NASA/RECON: 87A18475, 87A11334, 86A42620, 85X74308, 85X70592, 85A39670. 85A13519, 84X78036, 84X72894, 79X75706, 78N11082, 77A41993, 74N71316, 74N70964, 74A12920, 74A11559, 73N12847, 73N12840

Essential Element: MAIN PROPULSION

No: V2.1 **Title:** Eliminate Separate OMS and RCS

Operations Requirement:

Delete OMS and RCS as separate systems from MPS.

Rationale:

If MPS can be utilized for OMS and RCS, it may significantly lighten vehicle and will simplify ground support operations.

Sample Concept:

Use one of MPS engines at greatly reduced throttle for final orbit insertion and de-orbit. This eliminates separate engines, valves, thrust structure and tankage with a modest increase in on-board MPS tankage.

The integrated propulsion system would provide hot gas for the RCS configuration.

Concept dependent on booster and orbiter having independent propulsion and tankage as proposed in STAS.

Technology Requirement:

1. Develop throttleable MPS; same as Item V2.3
2. Develop orbital restart capability
3. Develop Zero-G propellant acquisition techniques

Technology References:

See V2.

Essential Element: MAIN PROPULSION

No:V2.2 **Title**: No Turbopumps / use PFLB

Operations Requirement:

The ideal requirement is to eliminate turbopumps.

Rationale:

Turbopumps are very costly to develop and manufacture: heavy, very high RPM, cavitation-sensitive devices.

Rocket engine cost, refurbishment frequency, refurbishment cost, and T&C/O time consumption are largely driven by turbopump sensitivity.

Pressure-fed engines are a viable prospect as specific impulse is relatively insensitive to chamber pressure.

Sample Concept:

Develop a low-pressure-fed engine in the interest of providing minimum tankage weight and simplifying associated transport and handling GSE. A non-conventional nozzle will be necessary to shorten length and reduce weight.

Technology Requirement:

1. PFLB design no heavier than turbopump-type vehicle
2. Pressure-fed injector design
3. Igniter design
4. Plug nozzle design, toroidal thrust chamber, or other concept to shorten nozzle and increase low altitude thrust coefficient.

Technology References:

See V2.

Essential Element: MAIN PROPULSION

No: V2.3 **Title:** Fully Throttleable Engines (multi-phase)

Operations Requirement:

For upper stages, this is an alternate to straight pressure-fed engine but has higher related operations cost, since it doesn't eliminate turbopumps. Design and develop main propulsion system rocket engines that are fully throttleable from near 0 to 100%.

Rationale:

The SSMEs can be throttled from 65% to over 100% only. With multiple restart and lower thrust capability, the MPS could be used for orbital maneuvering and de-orbit (OMS); thereby saving cost, weight, and T&C/O of separate OMS systems.

Sample Concept:

Use tank-head start pressure-fed engine phase. Add a percentage of propellant to the chamber with a turbopump to increase mass flow. Gradually delete pressure-fed component to achieve maximum propellant mass flow. Thrust can then be tailored to mission profile to accommodate acceleration requirements.

Technology Requirement:

Must develop:

1. SSME multiple restart capability
   - Spark plug/arc
   - Hot resistor
   - Laser
2. Throttleability
   - Multi-phase concept
     - o Pressure fed
     - o Turbopump assist
     - o Full turbopump
3. MPS propellant acquisition technique for Zero-G restart

Technology References:

See V2.

Essential Element: MAIN PROPULSION

No: V2.4 **Title:** Soft Engine Start

Operations Requirement:

Revise rocket engine start-transient time specifications to allow significantly slower start time.

Rationale:

Existing SSME rapid start can reduce life expectancy and increase refurbishment frequency of turbopump bearings, seals, and propellant valves.

Sample Concept:

See operations requirement.

Technology Requirement:

None

Technology References:

See V2.

CIRCA 2000 REQUIREMENT DATA

Essential Element: MAIN PROPULSION

No:V3 **Title**: No Hypergols

Operations Requirement:

No use of hypergols for launch, orbital propulsion, or APU systems.

Rationale:

A very significant quantity of non-productive manhours occurs during each flow for "area clear" required during hazardous opening/entry/operation of OMS and RCS orbiter systems. There is also a snowballing effect in facilities and O&M requirements for special ventilation, scrubbers and a multitude of safety equipment, including a small army to use and maintain scape (self-contained atmospheric protective ensemble) suits. Further, a pound of hypergol costs about $8.00, whereas, a LOX/H2 mix costs less than $0.22/lb; a LOX/$CH_4$ mix costs less than $0.15/lb; and a LOX/$C_3H_8$ costs less than $0.08/lb.

Sample Concept:

Utilize portion of main propulsion for OMS. Adapt Space Station O_2/H_2 thruster for airborne/orbital RCS.

Technology Requirement:

Develop systems using prime propellants for OMS, RCS, and APU applications. (See v2.1).

Technology References:

(See V2)

Essential Element: MAIN PROPULSION

No: V4 **Title:** NO GN_2/He On-board Purges

Operations Requirement:

Delete launch vehicle on-board GN_2 and HE purge systems.

Rationale:

Subject systems add weight to vehicle and electro/mechanical/pneumatics require special small O&M army and much time for ground processing and launch.

Sample Concept:

Eliminate sources of hazardous fluid leaks such as bolted flanges with seals, flared fittings, etc. Utilize welded or brazed assembly techniques and/or Nitinol compression fittings.

Use lightweight airborne mass spectrometer with sensing lines or design vehicle with multitude of very small, lightweight electronic fuel and oxidizer sensors capable of verifying leak-tight vehicle configuration. Load fuel first. Verify system leak-free, then load oxidizer. If leak is detected during propellant loading, detank and assess.

Technology Requirement:

Develop MPS engine requiring no purge prior to firing in atmosphere.

Lightweight mass spectrometer for launch and flight environment.

Consider Nitinol fittings, particularly for hard-to-reach connections.

Technology References:

NASA/RECON: 86X71562, 86N21849, 85X76796, 85X76476, 85X73181,
85N21386, 85A47011, 84K10941, 84A42759, 82X78166

CIRCA 2000 REQUIREMENT DATA

Essential Element: ATTITUDE/RENDEZVOUS CONTROL

No:V5 Title: No Gimballed Engines

Operations Requirement:

Devise thrust vector or vehicle attitude control system which eliminates need for gimballed engines and associated hydraulics, seals, pivots, bellows, etc.

Rationale:

Gimbal systems are expensive and heavy, and add a severe burden of O&M, and test and checkout to ground support operations.

Sample Concept:

Using multi-engine concept, and off-center thrust vectors, use differential throttling for trajectory control. Accept less than "normal" TVC angle specifications. Reexamine the flight dynamics models to determine if the TVC requirements can be reduced to a point where methods other than gimballing would be acceptable.

Technology Requirement:

Throttleable engines; see Items V2.2 and V9 TVC concepts.

Technology References:

See V8.

Essential Element: FAULT TOLERANT AVIONICS

No:V6/T8 **Title:** Integrated Fault Tolerant Avionics Suite (IFTAS)

Operations Requirement:

Avionics systems must provide for higher reliability by providing increased levels of fault tolerance in support of mandated system availability.

Rationale:

To support onboard checkout and mission success the entire avionics suite must be designed to provide that level of fault tolerance required to assure that the system is available when required. This is best accomplished by assuring the robustness of all mission critical systems, and providing fault tolerance where it is required (similar to a minimum equipment list for dispatch of commercial aircraft).

Sample Concept:

Future systems must be designed such that systems in general can be dynamically configured to provide for more than one function. Should an allocated processor or sub-system fail, another processor with a lesser priority function should be assigned to reconfigure and perform the function of the failed processor. This forces a high degree of commonality, and distributed processing.

Technology Requirement:

Distributed processing, layered architectures, commonality.

Technology References:

NASA/RECON: 86N20475, 86N20472, 86N20402, 86A47511, 86A47442, 86A37043, 86A33194, 86A28062, 86A11452, 85X10244, 85N30643, 85N23337, 85N16896, 85N16752, 85N11610, 85N10711, 85A44565, 85A43489, 85A34179, 85A24795, 85A17876, 85A17344, 84A43946, 84A41699, 84A26771, 84A26768, 84A10052, 84A10001, 83N36337

Essential Element: ON-BOARD CHECKOUT

No:V7/T7 **Title:** Health & Status Monitoring (on-board checkout)

Operations Requirement:

Current configurations require extensive use of GSE to support vehicle checkout. Future systems should incorporate onboard checkout and minimize GSE.

Rationale:

Current configurations require complex GSE hookups to support system test and operational verification. The configuration verification, required for test hookup and calibration, defeats efficient operations. Commercial aircraft provide 100% onboard checkout.

Sample Concept:

After a firm set of test requirements has been defined, early in the design phase, the associated hardware/software required to support on-board testing must be incorporated in each subsystem. It is important to maintain subsystem self-test autonomy.

Technology Requirement:

Bit and Integrated Fault Tolerant Avionics Suite (IFTAS) with layered architecture.

Technology References:

NASA/RECON: 87N10079, 87A33872, 86N20489, 86A23765, 85N16753, 85N16897, 85N16898, 85N16900, 85A24795, 85A28633, 85N34596, 85A45398, 84N14754, 84N26573, 84N34500, 84A46661, 83A45473

Essential Element: TVC/GN&C

No: V8 **Title:** TVC by Delta Thrust and/or RCS/or Aero

Operations Requirement:

Provide TVC or some form of vehicle attitude control during MPS operation if gimballed engines are eliminated.

Rationale:

Simplifying the vehicle systems and ground operations by deleting gimballed engines and associated systems requires alternate method of TVC or vehicle attitude control during MPS operation as proposed in Item V9.

Sample Concept:

Using multi-engine concept, and off-center thrust vectors, use differential throttling for trajectory control. Accept less than "normal" TVC angle specifications. Possible use of aerodynamic surfaces, also.

Technology Requirement:

Throttleable engines; see items V2.2 and V5 TVC concepts.

Technology References:

NASA/RECON: 87N16551, 87N11735, 87A33249, 87A32117, 87A19603, 86X75348, 86A28490, 85X74761, 85X73876, 85N22229, 85A45971, 85A41019, 85A39562, 85A24795, 84X77582, 84X72233, 84X10357, 84N72750, 84N24603, 84N12237, 84K10744, 84K10153, 84A40143, 84A43401, 84A29544, 84A29543, 84A26701, 84A16526, 84A11999, 83A11175

Essential Element: TVC/GN&C

No: V9 **Title:** No Hydraulics

Operations Requirement:

Provide high thrust actuators for vehicle systems using a system other than hydraulic.

Rationale:

Hydraulic systems are heavy, complex, and plagued with O&M GSE activities. Vehicle and ground support operations would be greatly simplified if simpler, more reliable alternative is developed.

Sample Concept:

State-of-the-art high-torque electric motors coupled to low-friction ball-worm linear actuators and high-leverage mechanical linkage hold promise of great simplification for ground support operations.

Technology Requirement:

Develop motors with ball-worm actuators and self-test status reporting for specific applications.

Technology References:

See V8.

CIRCA 2000 REQUIREMENT DATA

Essential Element: TVC/GN&C

No:V10 **Title**: Autonomous GN&C

Operations Requirement:

Eliminate vehicle dependence on GSE for test and checkout.

Rationale:

Onboard bit/bite of GN&C can eliminate/simplify/speed-up ground support operations.

Sample Concept:

Boeing 757/767 or advanced military aircraft computerized electronics providing self-test and fault identification with fault-tolerant computers. Ability to replace circuit boards without system shutdown. Easy accessibility. See items T7, T8, and T10.

Technology Requirement:

Further development of bit/bite.

Technology References:

See V8.

Essential Element: PROPELLANT TANKAGE STRUCTURE

No:V11 **Title**: Leak-Resistant Tank and Plumbing Design

Operations Requirement:

Develop cryo tank materials and designs providing greater leak-proof integrity; (fewer separable connections and leak paths).

Rationale:

Contemporary tankage and plumbing are leak sensitive and require constant ground operations vigilance. Any configuration simplification has positive consequences on ground support operations.

Sample Concept:

An integral tank containing concentric fuel and oxidizer tanks, (fuel and oxidizer must be thermally compatible), eliminating intertank structure and throughtank plumbing.

Propane and methane are cryogenic fuels that possess potential for common bulkhead concentric tanks. The least expensive, propane for instance, is well suited for this application because its normal freezing point of -305.8° F allows it to remain liquid at the normal boiling point of oxygen (-297.4° F). Another potential benefit of this concept is the densification by thermal conduction to the oxygen during propellant loading.

Technology Requirement:

1. Research in lightweight, internal insulation, easily applied and reusable without maintenance.

2. Development of innovative alloys retaining higher strength characteristics at cryo temperatures.

3. Development of an integral tank configuration with concentric fuel and oxidizer tanks; made possible by cryo-compatible propellants, i.e., LOX and methane or propane where cryo temperatures and/or fuel freezing point are close.

4. Greater use of welded joints; Nitinol sleeves and collars, etc.

Technology References:

NASA/RECON (See Volume 5):
87A33190, 87A13055, 87A13051, 87A13011, 87A11843, 86X75033, 86X74233, 86X73534, 86X10270, 86X10066, 86X10045, 86N22593, 86N13349, 86C12705, 86C00011, 86A40487, 86A36854, 86A36335, 86A31475, 86A31465, 85X746489, 85X10084, 85X10074, 85A46526, 85A45739, 85A43126, 85A41005, 85A39283, 85A37401, 85A37376, 85A35389, 85A27119, 84X73372, 84A34010, 84A32676, 84A28232, 83X72974, 83X72199, 83A37861, 83A33961, 82X73554, 82X71731, 82A47042, 82A38699, 82A24804, 82A23752, 80N30494

Essential Element: PROPELLANT TANKAGE STRUCTURE

No: V12 **Title:** One Oxidizer / One Fuel

Operations Requirement:

Simplify propellant procurement, transport, storage, pumping, safety equipment and procedures by designing vehicles using only one oxidizer and one fuel.

Rationale:

Each individual propellant ground system requires its own little army of engineers, technicians, safety, and expensive, hazardous facilities/GSE.

STS has five propellant components, each of which require separate procurement, transport, storage, pumping , GSE, safety, operational procedures, engineers, technicians, etc.

Sample Concept:

Propellant-related ground support operations and the different vehicle systems test and checkout would be immensely simplified if only one oxidizer and one fuel were required.

Technology Requirement:

Development only.

Technology References:

(See V2)

Essential Element: PROPELLANT TANKAGE STRUCTURE

No: V13 **Title:** No GN_2/HE Pressure Systems

Operations Requirement:

Delete GN_2 and HE valves control plumbing and propellant tankage pressure systems.

Rationale:

Elimination of GN_2 and HE storage bottles, supply valves, manifolds, plumbing, and multiple test and checkout, will significantly lighten the vehicle, and simplify and speed-up ground support operations.

Sample Concept:

Provide electro-mechanical valve actuators with electrical self-test/status capability. Propellant tank prepressurization at launch provided from cryo propellant boil-off with vent valve cycling as needed. Use gas generator or engine hot gas bleed/heat exchanger during flight a la STS.

Technology Requirement:

Design application of existing technology. Innovative vehicle design philosophy.

Technology References:

This document, Section 3.0.

Essential Element: LANDING GEAR

No:V14 **Title:** Integral Landing Gear

Operations Requirement:

Simple, rapid transit of flight vehicles through the ground processing cycle: from landing site, to processing facility, to launch pad.

Rationale:

The operational efficiency and cost reduction potential of this C2K concept are strongly dependent on capability to insert the payload cocoon as late as practical in the flow, i.e., immediately before vehicle transfer to pad. Use of integral landing gear and aircraft tug-type operation eliminate the need for large, O&M intensive crawler-transporter (CT) and mobile launcher platform (MLP) and allow rapid transit and reduced payload ground loiter time.

Sample Concept:

Booster and orbiter each feature integral landing gear. Each vehicle is capable of being towed by the same tug. The booster and orbiter land/rollout at high speeds. Orbiter download structures must be capable of landing speeds and accelerations. Towing to the pad can be over 20 mph.

Transit via integral landing gear also allows individual vehicle transfer to the pad and, with appropriate structural design (removable tension strut, perhaps), individual rotation - to - vertical about the landing gear using a mobile crane. This would provide the following benefits:

(1) Rapid/timely transfer of individual vehicles to pad.

(2) Minimum payload ground loiter time subsequent to insertion in vehicle.

(3) Requires roadway capable of supporting booster and orbiter individually, but crawler-transporter and mobile launcher platform are not required; gravelled crawlerway and repetitive dragging / smoothing not necessary.

(4) Erection GSE greatly simplified. At KSC mobile cranes are routinely maintained and available. Rotation to vertical can be accomplished without lifting flight vehicle from ground; assures full control of vehicle while "on-the-hook", greatly improving safety and quickness of the operation.

(5) For a ground processing scenario limited to horizontal vehicle handling, transit to pad can be either individual or piggyback. The C2K concept of individual transport promises a lighter booster.

No:V14 **Title**: Integral Landing Gear (Continued)

Technology Requirement:

No new technology needed other than improvement in brakes and tires.

Analysis of conventional vehicle and landing gear structures to assure erection capability (accommodation of X-axis loads).

Technology References:

This document, Section 3.0.

CIRCA 2000 REQUIREMENT DATA

Essential Element: MATING STRUCTURE

No:V15 Title: Non-pyrotechnic Separation

Operations Requirement:

Simplify vehicle separation design and related ground processing.

Rationale:

Contemporary stage separation hardware and ground processing are complex, hazardous, and manpower intensive.

Test and checkout of electrical systems for ignition of pyrotechnic devices is lengthy and wasteful of manpower during repetitive "area clear" operations. STS 51-1 preps for mating required a total clock time of 72 hours directly related to separation hardware and pyrotechnics installation and test.

Sample Concept:

The C2K concept of individual vehicle transit to pad and individual erection, suggests the geometric possibility of a vehicle back-to-back mating and separation system requiring no moving parts or pyrotechnics. Examination of the following process is suggested:

(1) Design booster and orbiter propulsion/ acceleration mechanics such that the booster acceleration component exceeds that of the orbiter, i.e., the booster wants to outclimb or run ahead of the orbiter.

(2) Erect the booster first. Subsequent rotation of the orbiter to vertical about its landing gear (over the flame trench, onto a thrust butt) can allow automatic attachment of the orbiter to the booster by means of a male/female clevis arrangement having no moving parts or pyrotechnics. The orbiter is effectively impaled on the booster.

(3) When the booster propellants are expended, aerodynamic drag and orbiter acceleration provide stage separation.

Technology Requirement:

Detailed examination of aerodynamics and related shock-wave interactions would be necessary to assure validity of separation dynamics.

Either a twin-hull booster, or an exterior payload bay (or other alternative) will be required to eliminate structural interference of the vehicles during erection of the orbiter.

Technology References:

This document, Section 3.0.

Essential Element: TPS

No: V16 **Title:** No Separable TPS

Operations Requirement:

Eliminate time consuming, critical inspection and test of orbiter-type TPS.

Rationale:

Orbiter tile has structural characteristics akin to high-density styrofoam, i.e., its brittle and delicate. Strength of bond to vehicle substrate is critical and very difficult to ascertain. repair/test/validation of TPS is very time consuming, requires expensive GSE and high-tech test equipment, and multiple eyes to observe/verify procedures.

Sample Concept:

Provide simplified, skin-integral, large panel, "old technology" TPS, i.e., temperature resistant pyrolytic graphite, metals and composites as proposed for earlier STS concepts. Reexamine, redefine reentry mode to multi-skip, once-around reentry a la Sanger, and reexamine cross-range requirements impact on TPS configuration.

Technology Requirement:

Development only. Previous studies/designs utilized much less sensitive TPS.

Technology References:

NASA/RECON: 85X10346, 85A38450, 85A28801, 85A17092, 84X74531, 84X10382, 84X10381, 84X10379, 84X10375, 84X10372, 84X10371, 84X10366, 84X10356, 84N32505, 84N24709, 84A47046, 84A42651, 84A41928, 84A37496, 84A37494, 84A37493

Essential Element: ENERGY STORAGE

No: V17/T11 **Title:** High Density Energy Storage (ground power unnecessary)

Operations Requirement:

Onboard power source capable of providing sufficient power for ground O&M, T & C/O, and launch operations without connection to facilities or GSE.

Rationale:

Ground power requirements with associated GSE and umbilicals complicate ground processing and require a supporting organization. This results in vehicle "power-up" being a costly repetitive milestone in STS processing. It should be routine such as 767, B-1, etc.

Sample Concept:

High density energy storage systems, such as regenerative fuel cells or sodium/sulphur batteries to provide on-board power. Fuel cells should be capable of using propellant grade H_2 and O_2.

Technology Requirement:

Accelerated development of energy storage systems with emphasis on fuel cells and sodium/sulphur batteries.

Technology References:

NASA/RECON: 87X70518, 87N22801, 87N19811, 87N19809, 87N17397, 87N16453, 87N14860, 87N12998, 87A33793, 87A33790, 87A33778, 87A33787, 87A15901, 87A14170, 86X73564, 86X73563, 86X72121, 86X71138, 86X70734, 86N28331, 86N28329, 86N27586, 86N23047, 86N17886, 86N16734, 86N16495, 86N14764, 86C12215, 86B10483, 86B10277, 86A37201, 86A36369, 86A24845, 85X76813, 85X72247, 85N71096, 85N33588, 85N16292, 85N31372, 85N13880, 85N13850, 85A45422, 85A33144, 85A26700, 85A26501, 85A12599, 84X75772, 84N31535, 84N12246, 84N10493, 84A30956, 84A30107, 84A30103, 83N14683, 81N22305, 81K10462, 80A20128, 75N24837

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Essential Element: VEHICLE DESTRUCT

No:V18/S4   Title: No Ordnance

Operations Requirement:

Eliminate all ordnance devices or provide ordnance which is inherently safe forhandling purposes. Ordnance elements, if required, must be introduced in to the processing flow with the minimum possible impact. The objective would be to eliminate or drastically reduce "area clear" requirements levied by ordnance activities.

Rationale:

There are five types of ordnance devices currently used on STS: propulsion (SRM's), ignition, release, separation, and range safety. The special handling safety, area clear, and training requirements make this a major cost area in ground processing.

Sample Concept:

Eliminate explosive ignition devices: replace pyrotechnics with lasers.

Explosive release and separation devices: replace with electromechanical and Nitinol initiated devices, or simple-geometry clevis-type attachments.

Explosive range safety devices: eliminate by using military weapon systems to destroy errant vehicles. Use vehicle-borne beacon to assure identification and assist weapon. (See V19)

Technology Requirement:

Development only.

Technology References:

NASA/RECON: 86N27356, 86A23512, 85N13959, 85A47011, 84A42759, 82N72580, 82N19033, 80X73875

Essential Element: VEHICLE DESTRUCT

No: V19 **Title:** Independent Weapon Destruct

Operations Requirement:

Provide ground-based anti-missile-type battery of Circa 2000 weapon systems to provide near-range vehicle destruct. Eliminate extensive non-productive manhours for "area clear" during range safety ordnance installation. Minimize "safety army" and procedures that accommodate contemporary systems and methods.

Rationale:

Elimination of vehicle range safety ordnance and associated non-productive manhours and operational cost is highly desirable.

Sample Concept:

Delete the extensive vehicle/ground remote destruct system. If an unmanned vehicle goes awry during the first minutes of launch (or close to launch site) use ground based anti-missile weapons to provide range destruct. Use beacon on-board space vehicle to assist in identification and guidance.

Technology Requirement:

None. Use military anti-missile system of Circa 2000 vintage .

Technology References:

(Classified)

C I R C A   2 0 0 0   R E Q U I R E M E N T   D A T A

Essential Element: PAYLOAD

No: V20/T2   **Title:** Payloads: Standard Autonomous Cargo Container or Alternate Passenger Container (self-sufficient)

Operations Requirement:

Provide only simple mechanical interface between launch vehicle and payload.

Rationale:

Orbiter payload bay mods and payload flight support equipment software mods are among the most time consuming ground support operations.

See Item T2 (payload T&C/O).

Sample Concept:

Develop a payload bay module consisting of orbiter-universal strongback and environmental cover (as needed) that has internal capability to support payload electrical, environmental, and communications requirements from loading until orbital placement. This philosophy is also applicable to man-carrying orbital delivery module with life support systems. Concept is dependent upon forcing payload designers to accommodate the launch vehicle rather than vice-versa.

Technology Requirement:

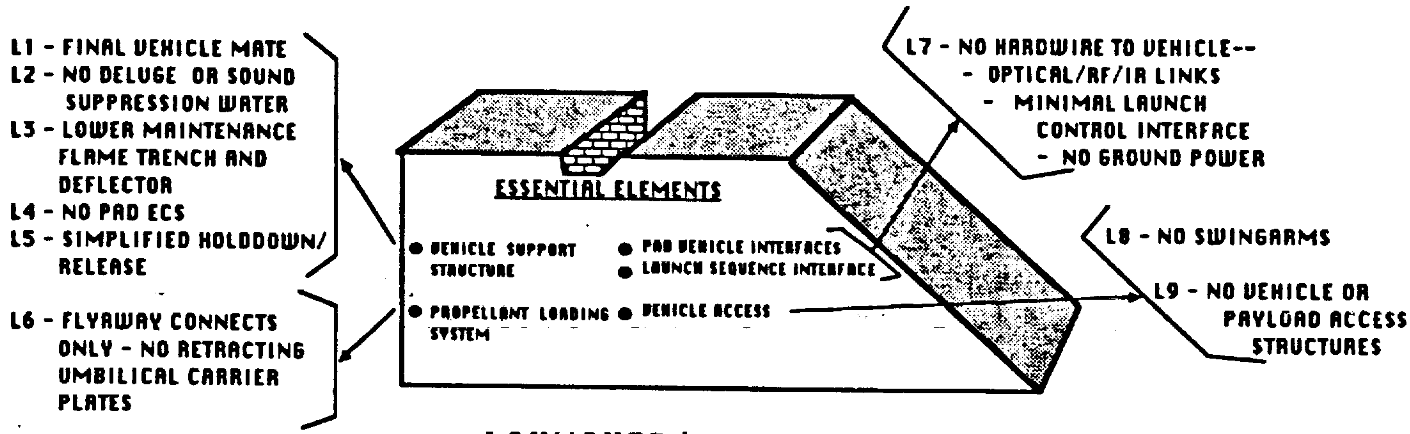
Longer-life, more reliable (high density) fuel cells or other source to support payload module. See V17.

Technology References:

NASA/RECON: 86A14382, 84A11721, 78A51985, 76N27347

See also V17.

Launcher / Pad



LAUNCHER/PAD

CIRCA 2000 SYSTEM OPERATIONAL REQUIREMENTS

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CIRCA 2000 REQUIREMENT DATA

Essential Element: VEHICLE SUPPORT STRUCTURE

No: L1 **Title:** Final Vehicle Mate

Operations Requirement:

Eliminate complex rotation, mate, and associated GSE and bridge cranes in VAB vehicle-mating scenario. Also eliminate need to transport very large, delicate, awkward assembly to launch site.

Rationale:

Mating remotely from launch site requires army of men and GSE for complex lifting/rotation harness, bridge cranes, MLP, CT, platform retraction and the very expensive, labor intensive O&M "tree" necessary to support all this equipment.

Sample Concept:

"Barren Pad" equipped with very simple aft rotation/pivot wheel-stop at the flame trench edge. Individual stages rolled relatively quickly to pad on integral landing gear (reusable vehicles). Individual stages rotated to vertical from opposite sides of flame trench using aft rotation/pivot and large mobile crane selected for positive control design and horizontal-restraint winch. Vehicle "nesting" concept greatly simplifies pad configuration.

One of the prime limitations of mobile crane support is the payload "swinging pendulum" effect. This same effect is also a serious operational hazard with bridge cranes, e.g., KSC/VAB. Mobile cranes have been successfully used in place of the MDD to lift orbiters for mate/demate with the SCA on four occasions. Inability to restrain the load pendulum resulted in severe wind-speed limitations during those operations. Rotation about integral landing gear or special dolly wheels would retain vehicle ground contact at all times and eliminate the pendulum hazard normally associated with both bridge and mobile cranes.

Any large industrial facility (such as a major launch site) routinely requires large mobile crane support for a multitude of logistics and O&M tasks. Using such a system (carefully selected for capability) for vehicle erection at the launch site is like acquiring an erection system virtually for "free".

With this concept, final stage mating and separation system verification must occur after erection at the pad. This may necessitate a special mobile vehicle for access to the interstage connect points. The same mobile vehicle can be designed to provide passenger access to launch vehicle subsequent to propellant loading.

Further simplification would result from booster/orbiter connection of clevis-type fittings secured by weight or acceleration forces in place of the usual explosive bolts.

Technology Requirement:

Development only.

Technology References:

This document, Section 3.0.

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C I R C A   2 0 0 0   R E Q U I R E M E N T   D A T A

Essential Element: VEHICLE SUPPORT STRUCTURE

No: L2 **Title:** No Deluge or Sound Suppression Water

Operations Requirement:

Eliminate very extensive facilities, personnel, test and checkout procedures, and costly O&M of pad water systems.

Rationale:

Gross simplification of launch pad facilities and operations is essential to reduce cost-to-orbit by factor of 10.

Sample Concept:

Proposed pad has no towers or access structures other than lightning-arrest towers and cables.

Firex/deluge water necessary to protect swing arm hydraulics, propellants, pneumatics, electrical cabinets and tower/MLP deck are all eliminated by the "barren pad" concept.

Sound suppression water of the STS system is necessary to protect the launch vehicle and MLP from the low frequency, high energy acoustics generated by the SRBs. There are no SRBs in the Circa 2000 concept.

Technology Requirement:

None.

Technology References:

This document, Section 3.0.

Essential Element: VEHICLE SUPPORT STRUCTURE

No: L3 **Title:** Lower Maintenance Flame Trench and Deflector

Operations Requirement:

Simplify flame trench and deflector to eliminate repetitive, costly maintenance.

Rationale:

Replacement of firebrick, major refurbishment at lengthy intervals, and consistently high structural erosion of flame deflectors is costly. These should be greatly reduced or eliminated.

Sample Concept:

Construct the new pad with typically deep pilings and footers, although not necessary to support weight of MLPs and towers (they aren't used in proposed pad). Dredge very deep pond at base of flame trench (40-60 ft. deep). Connect by low maintenance canal to banana river or nearby body of water. Deep water will serve to quench exhaust and act as flame deflector.

Technology Requirement:

Investigate water depth requirement as function of thrust level and rocket engine geometry.

Technology References:

This document, Section 3.0.

CIRCA 2000 REQUIREMENT DATA

Essential Element: VEHICLE SUPPORT STRUCTURE

No: L4 **Title:** No Pad ECS

Operations Requirement:

Delete extensive/costly equipment and personnel providing pad GN_2 purge and pressurization at launch. Also delete similar systems providing vehicle ECS.

Rationale:

These are costly in O&M personnel and test/checkout/pre-launch validation time, and are purposely deleted in the proposed "barren pad".

Sample Concept:

No vehicle on-board work is done at the pad other than erection, propellant loading and communications/controls connect/ positioning. Therefore, no ground-provided vehicle ECS is required. Payload canister is autonomous (manned or unmanned).

Proposed pad blast area does not include offices, shops, restrooms, or routinely occupied areas; only propellant lines, communications/controls and hold-down/umbilical access tunnels.

Technology Requirement:

None.

Technology References:

This document, Section 3.0.

Essential Element: VEHICLE SUPPORT STRUCTURE

No: L5 **Title:** Simplified Holddown/release

Operations Requirement:

Greatly simplify vehicle holddown systems at pad.

Rationale:

Holddown system of some kind is mandatory to restrain vehicle in high winds and to stabilize motion during complex engine start sequences. Existing method is costly, dangerous, and time-consuming.

Sample Concept:

Eliminate explosive aspect of bolts, and ultra-high bolt torqueing. Nitinol mechanisms hold promise of holddown/release systems having no pyrotechnics or moving-linkage mechanisms.

Technology Requirement:

Innovative holddown and release mechanism using Nitinol technology/mechanism development or equal. Reexamine holddown philosophy with goal of simplification.

Technology References:

This document, Section 3.0.

CIRCA 2000 REQUIREMENT DATA

Essential Element: PROPELLANT LOADING SYSTEM

No: L6 **Title:** Flyaway Connects Only - No Retracting Umbilical Carrier Plates

Operations Requirement:

Provide simplified vehicle umbilical disconnect systems.

Rationale:

Contemporary quick-disconnect/swingarms umbilical carriers are very complex, launch-damage susceptible, and manpower-intensive for test and checkout. Post-launch refurbishment is repetitive, costly, and time consuming.

Sample Concept:

Proposed pad has no vehicle access towers, swingarms or retracting umbilical carrier plates. All hard connects to the vehicle (essentially propellant lines) are vertical lift-off type with simple, gravity operated protective covers for QDs and carrier plates.

Technology Requirement:

None.

Technology References:

This document, Section 3.0.

Essential Element: PAD VEHICLE INTERFACES; LAUNCH SEQUENCE INTERFACE

No: L7 **Title:** No Hardwire to Vehicle;
Minimal Launch Control Interface;
No Ground Power

Operations Requirement:

Minimize hard connections to vehicle to simplify vehicle erection and pad connection sequence. Also, drastically reduce quantity of control functions from LCC to pad.

Rationale:

All systems must be dramatically reduced or simplified to achieve cost reduction. O&M of vehicle hard connects is costly and labor intensive.

Sample Concept:

Vehicle electrical power is self-contained via high density power cells. Essential ground control functions are relayed to the vehicle via RF, infrared, or equivalent non-hard-connect to vehicle. Vehicle connects limited to propellants, holddown mechanism, and electrical ground.

Technology Requirement:

Remote RF and infrared control techniques are in existence. No technology breakthrough required except development of high-density energy cells (see V17).

Technology References:

NASA/RECON: 86A15396, 85A10576, 84X74058, 84X73435, 82A28585, 84A26450, 82N76663, 82N12314

See also V17.

C I R C A   2 0 0 0   R E Q U I R E M E N T   D A T A

Essential Element: VEHICLE ACCESS

No: L8   **Title:** No Swingarms

Operations Requirement:

Simplify or eliminate all ground support operations, equipment, and structures to dramatically reduce repetitive costs. Eliminate repetitive tests and checkout at pad and post launch refurbishment.

Rationale:

Contemporary swingarms are expensive, complex, O&M intensive, and launch critical systems.

Sample Concept:

Proposed pad and vehicle are very much simplified compared to conventional concepts. Vehicle simplification, as proposed in other items herein, eliminates dependence on multi-level vehicle access/connections provided by swingarms. Payload canister inserted during T&C/O prior to transfer to pad. Passenger access via special mobile manlift.

Technology Requirement:

Concept dependent on development of simplified vehicle by related technology developments proposed in other items herein.

Technology References:

This document, Section 3.0.

CIRCA 2000 REQUIREMENT DATA

Essential Element: VEHICLE ACCESS

No: L9 **Title:** No Vehicle or Payload Access Structure

Operations Requirement:

Minimize vehicle resident time at pad. Rollout, erect, fuel, verify satisfactory self-test, launch.

Limited LRU changeout capability at pad (boattail and passenger manlift access).

Rationale:

Current STS requires two weeks or more at the pad for extensive interface systems test and checkout, payload access for O&M, vertical P/L insertion, closeout and all-systems verifications. This time period and tedious process is not acceptable for reduced cost and high launch rate.

Sample Concept:

Simplified vehicle and pad are key to reduced time at pad. Passenger access to the payload bay (passenger module) subsequent to propellant loading can be by mobile vehicle such as special elevated man-lift).

Mandatory access for vertical payload insertion would return the likelihood of costly structures and O&M army compromising the "barren-pad" concept.

Technology Requirement:

1. Design and development of modified/special mobile man-lift for passenger ingress/egress and access between stages to effect interstage attachment and separation system verification (if mandated).

2. Consideration of mobile payload transporter with elevated lift capability, if vertical access is absolutely mandatory.

3. Mobile crane capability at KSC is historically and operationally well established, possesses excellent safety record, is highly reliable, and flexible, and falsely underrated for operational use. Vehicle, payload, and passenger support using some form of mobile crane-adapted system should be considered to retain "barren-pad" concept.

Technology References:

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3.0 CIRCA 2000 EXAMPLE

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3.0 CIRCA 2000 EXAMPLE

"It must be remembered there is nothing more difficult to plan, more doubtful of success, nor more dangerous to manage than the creation of a new system. For the initiator has the enmity of all who would profit by the preservation of the old institution and merely lukewarm defenders in those who would gain by the new ones."

Machiavelli, The Prince, 1513

This section addresses the "creation of a new system", a "next generation" reusable delivery system having the potential to reduce cost/pound-to-orbit by a factor of 10 as compared to STS. The system concept is called Circa 2000, or simply, C2K. It is **NOT** an attempt to design flight vehicles. It IS an attempt to define some of the factors which have driven the repetitive ground processing timeline of STS to become 18 times greater (at best) than the 160-hours originally envisioned by STS program management and their design teams. It IS an attempt to show why STS costs almost $5,500 (1985) to deliver a pound of payload to LEO.

The C2K concept presented herein is entirely driven by the ground processing facilities, GSE, and vehicle systems operational test and checkout requirements. What does that mean? It means the normal process of designing flight hardware for performance only is a cost time bomb. It means the next generation of vehicles MUST be designed to achieve the lowest practical life cycle cost (LCC). That means design MUST consider ease of maintainability. the systems must be simple, robust, easily accessible for O&M, and require much less O&M than ever before. The total system configuration must lend itself to the simplest possible ground processing facilities, GSE, launch site, and processing operations scenario. This results in the smallest possible operations headcount; a factor directly influenced by quantities and complexity of systems on a vehicle.

C2K presents an unprecedented challenge to designers to conciously and premeditatedly turn their entire technical thought processes upside-down. C2K challenges conventional design and development processes to include representatives of the operations world to assist in configuration evaluation and assessment with regard to LCC at the preliminary design/concept stage. Simplification and time/cost reduction must be attacked in an almost vicious manner. Conventional design thinking and resultant hardware will only ignite that cost time bomb.

The remainder of this section presents a generic launch vehicle with a configuration meeting a set of conceptual ground rules and assumptions aimed at reducing ground processing time and headcount to an absolute minimum. The interactive results of the vehicle and facilities on processing timeline and headcount will be shown in some detail based on a C2K comparison with STS processing procedures, timeline, and headcount.

The results are remarkable. Simplification of vehicles and facilities is highly synergistic. Each system or operation deleted (or greatly simplified) has a snowballing ripple effect through the entire launch operations organization. The result is exponential. Application of these principles promises to reduce that $5,500/lb-to-orbit by a factor closely approaching 10. Figure 3.0-1 shows the basic time cube and its influence factors. For instance, it is discussed herein that the C2K total program headcount works out to be 39% of the Sept. 1985 STS/KSC equivalent. This alone, coupled with C2K vehicle and facilities simplification with triple the STS launch rate, indicates a life cycle cost for launch operations of .39/3 or 13% of STS.

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3.1 G R O U N D O P E R A T I O N S P R O C E S S I N G F L O W

Section 3.1 describes the vehicle and facilities ground rules and assumptions for the sample ground processing flow that follows.

3.1.1 F L I G H T V E H I C L E G R O U N D R U L E S and A S S U M P T I O N S

1. Circa 2000 (C2K) is a two-stage, liquid propellant, parallel mated, vertical launch, orbital access system with glideback booster and payload-carrying orbiter.

2. C2K has 2/3 the quantity of major vehicle elements:
   - o STS: Orbiter, SRBs, ET
   - o C2K: Orbiter, booster

3. The vehicles are dramatically simplified in comparison to STS. Many radical, innovative engineering and design concepts will have been applied to C2K with a goal of minimizing quantities, types, and complexity of systems.

4. Vehicle transfer through the ground processing loop will be greatly simplified by the use of integral landing gear for booster and orbiter.

5. Vehicle O&M/T&CO will be performed in a horizontal attitude. Payload insertion and download removal will be performed at a single location, likewise in a horizontal attitude.

6. Test and checkout of the vehicles subsequent to a normal mission will be nearly autonomous and self-contained. Built-in test will be the norm.

3.1.2 F A C I L I T I E S / G S E G R O U N D R U L E S and A S S U M P T I O N S

1. C2K will share no STS facilities or GSE. Exceptions may include (if located at KSC) such items as the SLF, existing payload processing facilities, MMSE, mobile tugs, mobile cranes, contingency landing sites and secondary landing site aids and support operations.

2. C2K requires about one-half the quantity of equivalent STS major facilities.
   - o STS: Pad A, Pad B, VAB, OPF, RPSF, VPF, O&C, HMF (8 each)
   - o C2K: One barren pad, OPF, VPF, O&C (4 each)

3. C2K has no Mobile Launcher Platform/Crawler Transporter (MLP/CT).

4. C2K utilizes a "barren pad" concept with no vehicle access; no processing structures; and drastically simplified GSE and design philosophy. Because of this simplicity and the reduction of facility damage during catastrophic anomaly, only one pad is mandatory.

5. C2K vehicle rotation is performed at the pad using contemporary-design mobile cranes whereby each vehicle is rotated about its landing gear onto uniquely designed thrust butts. The vehicles always remain in touch with the ground, simplifying rotation, and providing greatly improved load control and safety. Rotation is assisted (controlled) during the final phase by a supplementary wire rope winch located on the mobile crane. Mating of the booster and orbiter is accomplished during rotation of the orbiter.

6. Payloads will be assembled and checked-out, either horizontally or vertically, with rotation to horizontal into a supporting strongback or support assembly. Payloads will then be placed in an autonomous canister or cocoon capable of providing power, communications, command, and environmental control with very little or no launch vehicle interface; transported to the vehicle, inserted, and launched. Vehicle and payload time at the pad prior to launch will approximate 24 hours maximum.

7. There is no STS-type Launch Control Center (LCC) for C2K. Test and checkout is locally controlled and autonomous within the vehicle while being processed in the facilities. For C2K, a very limited capability LCC is envisioned. The C2K LCC only initiates queries and receives data from the vehicle at the pad for launch readiness verification and terminal countdown / ignition sequence.

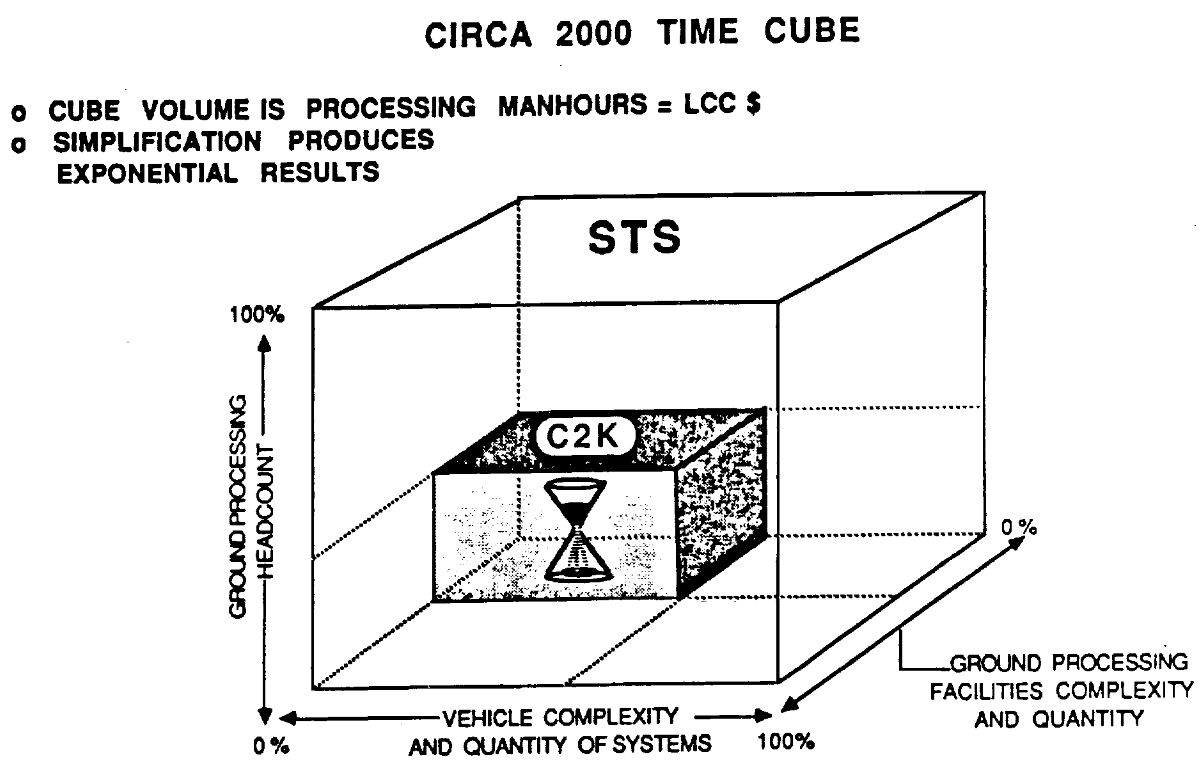
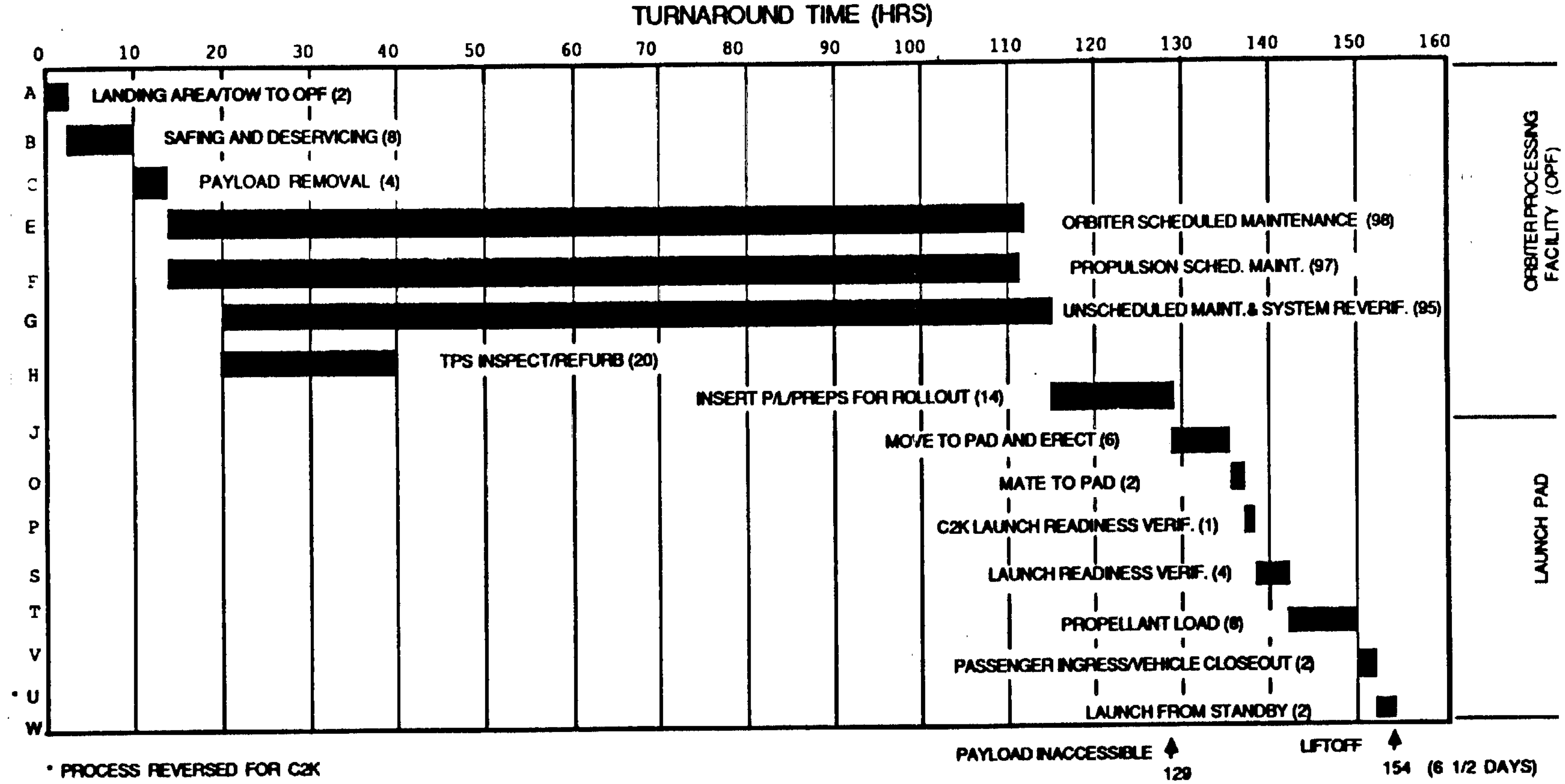


FIGURE 3.0-1
GROUND PROCESSING TIME CUBE

3.1.3 PROCESSING FLOW EXAMPLE

154-HR TURNAROUND ESTIMATE



- o TOTAL C2K ORBITER PROCESSING TIME - 571 HRS
- o C2K ORBITER POTENTIAL PROCESSING TIME - 363 HRS (SUM OF ABOVE BARCHART TIMES)

Figure 3.1-1
C2K 154-HR TURNAROUND ESTIMATE (PAYLOAD INSTALLATION AT OPF)

3.1.2 F A C I L I T I E S / G S E G R O U N D R U L E S and A S S U M P T I O N S (Continued)

4. C2K utilizes a "barren pad" concept with no vehicle access; no processing structures; and drastically simplified GSE and design philosophy. Because of this simplicity and the reduction of facility damage during catastrophic anomaly, only one pad is mandatory.

5. C2K vehicle rotation is performed at the pad using contemporary-design mobile cranes whereby each vehicle is rotated about its landing gear onto uniquely designed thrust butts. The vehicles always remain in touch with the ground, simplifying rotation, and providing greatly improved load control and safety. Rotation is assisted (controlled) during the final phase by a supplementary wire rope winch located on the mobile crane. Mating of the booster and orbiter is accomplished during rotation of the orbiter.

6. Payloads will be assembled and checked-out, either horizontally or vertically, with rotation to horizontal into a supporting strongback or support assembly. Payloads will then be placed in an autonomous canister or cocoon capable of providing power, communications, command, and environmental control with very little or no launch vehicle interface; transported to the vehicle, inserted, and launched. Vehicle and payload time at the pad prior to launch will approximate 24 hours maximum.

7. There is no STS-type Launch Control Center (LCC) for C2K. Test and checkout is locally controlled and autonomous within the vehicle while being processed in the facilities. For C2K, a very limited capability LCC is envisioned. The C2K LCC only initiates queries and receives data from the vehicle at the pad for launch readiness verification and terminal countdown / ignition sequence.

3.1.3 PROCESSING FLOW EXAMPLE

3.1.3. A C2K TIMELINES

A summary of the C2K ground processing timeline, as developed in Appendix B, is tabulated in Section 3.2.2-B. The C2K orbiter timeline totals 571 hours (544 + 27) for the STS-comparable functions A through W. Booster processing is quite similar, but requires only 499 hours, and is performed in parallel facilities. Figure 3.1-1 is the C2K orbiter timeline developed from the same data, but shows a clock timeline of only 154 hours; an apparent contradiction. However, the 154-hrs is the Appendix B estimated process time further developed to consider electrical/ electronic; mechanical/airframe; and propulsion work as parallel workload categories (and other assessments of parallel process possibilities not directly related to vehicle maintenance).

Orbiter maintenance items E and F are shown at 98 and 97 hours respectively, the full C2K-estimated timelines (parallel workload not rated as a driving factor). Unscheduled maintenance item G, however, estimated fully at 260 hours was reduced to the 95 hours shown by the above parallel workload rationale. This one arbitrary assumption provides a majority of the timeline reduction from 571 to 363 potential hours shown in Figure 3.1-1.

Figure 3.2-2, and accompanying text, further flags the vehicle maintenance "bottleneck", and through identification of further potential parallel workload (headcount effect not assessed) provides a further timeline reduction from 571 to 195 hours (Table 3.2-1).

Reduction of vehicles maintenance quantity and complexity, and simplified access, are the major requirements for timeline reduction.

3.1.3.B C2K EQUIPMENT AND FACILITIES ILLUSTRATED FLOW

The following figures supplement the ground processing barchart of Figure 3.1-1 to show a potentially simple C2K Space Center layout concept.

Figure 3.1-2 is an overall isometric sketch of a typical launch site concept showing the major facilities; focusing on the "barren pad" concept.

Figure 3.1-3 shows a close-up sketch of how the processing facility might look with the nearness of shops/labs and engineering offices accentuated.

Figure 3.1-4 examines the static loads during erection of a theoretical orbiter and payload having a net dry weight of 230K lb. The C2K concept utilizes a mobile crane for this operation. For the approximate geometry shown, the vertical-lift crane capacity could be expected to require only 15 to 20% (A) of the net load weight (B). The maximum vertical lift requirement is at initial lift; the load decreasing to zero at CG/pivot point vertical alignment (C). The lift point would need to be slightly aft of the initial lift point to pull the CG through the null point.

3.1.3 PROCESSING FLOW EXAMPLE

Figure 3.1-2

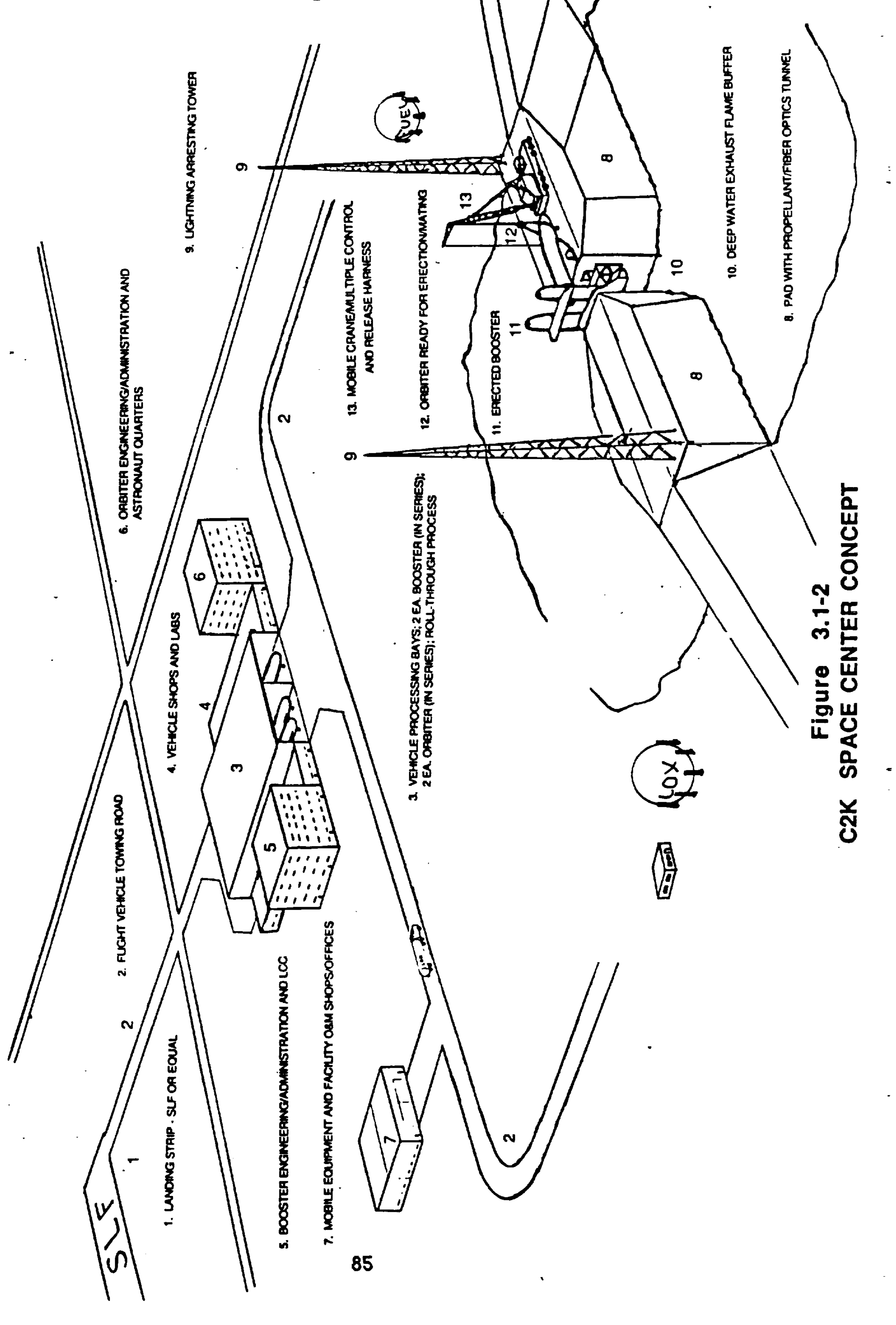


Figure 3.1-2
C2K SPACE CENTER CONCEPT

3.1.3.B C2K Equipment and Facilities Illustrated Flow (Continued)

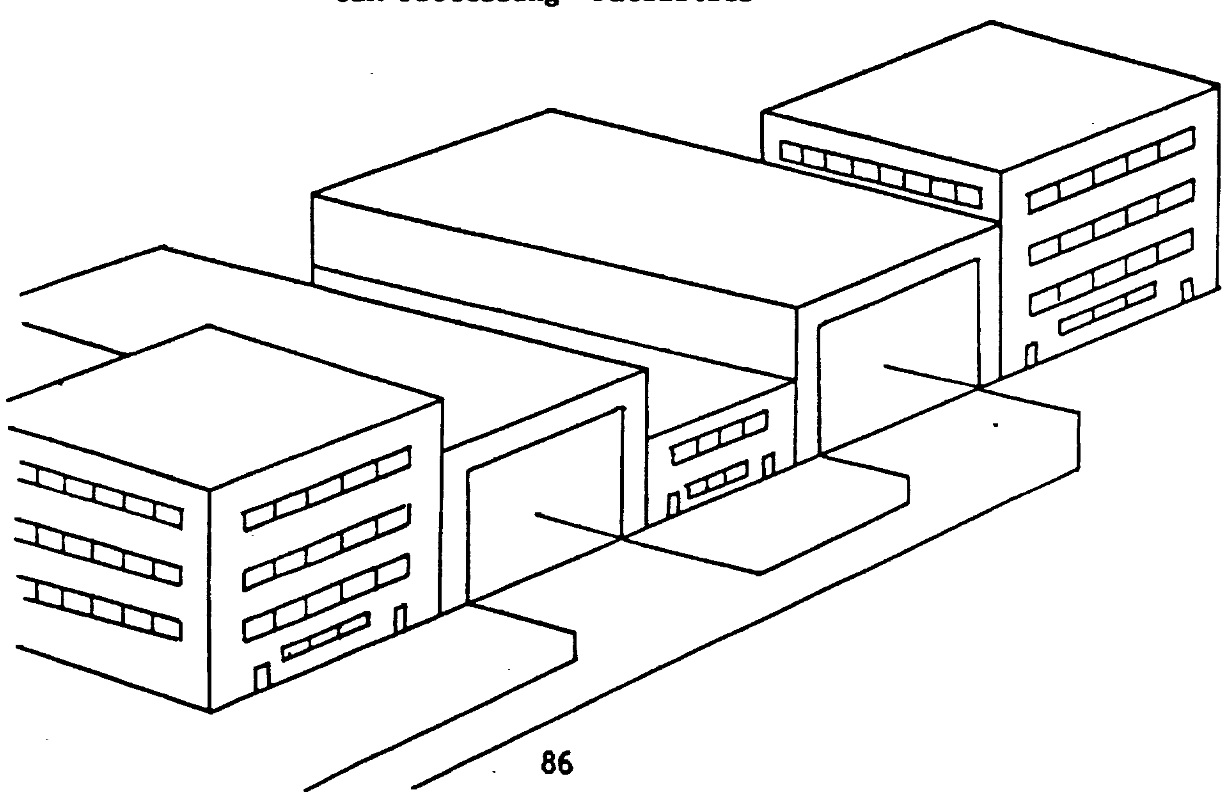
Beyond the rotational angle of (C) the vehicle will continue rotation onto the thrust butt by gravitational energy which must be controlled to prevent excessive acceleration and vehicle damage. The C2K concept provides that control by use of a heavy-lift winch integral with the mobile crane. For the approximate geometry shown the maximum horizontal control component would be 67K lb (D) or about 30% of net vehicle weight.

A propellant/fiber optics routing tunnel opens in the vertical wall of the flame trench at the thrust butt/vehicle interface. Propellant flanges could be designed with geometry to allow simultaneous mating with the vehicle at thrust butt seating; simplifying mate and disconnect at liftoff.

Design concerns included +X axis landing gear/vehicle loads; rotation harness attachment and removal from the vehicle; horizontal anchoring of the mobile crane; landing gear retraction technique; propellants and fiber optics interface; and perhaps more importantly -- back-to-back mating of the vehicles. All of these concerns (except mating, perhaps) are considered, by this study, to be amenable to contemporary design techniques. A twin-hull booster is shown in the concept because it is one of the solutions available for automatic vehicle alignment and mate of the stages; and eliminates geometrical interference of single-cylinder stages.

Figure 3.1-5 shows a design concept for a vehicle rotation harness attachment fixture. It accommodates 1) the initial vertical lift, 2) horizontal control during final rotation, and 3) a simple method for remote release and recovery of the rotation harness subsequent to completion. The design philosophy here is to eliminate the need for high crew, mobile manlift, or fixed pad structure to provide elevated access for removal of the rotation harness. These things all take time and unexpectedly large headcount to use and maintain.

Figure 3.1-3
C2K Processing Facilities



3.1.3 PROCESSING FLOW EXAMPLE

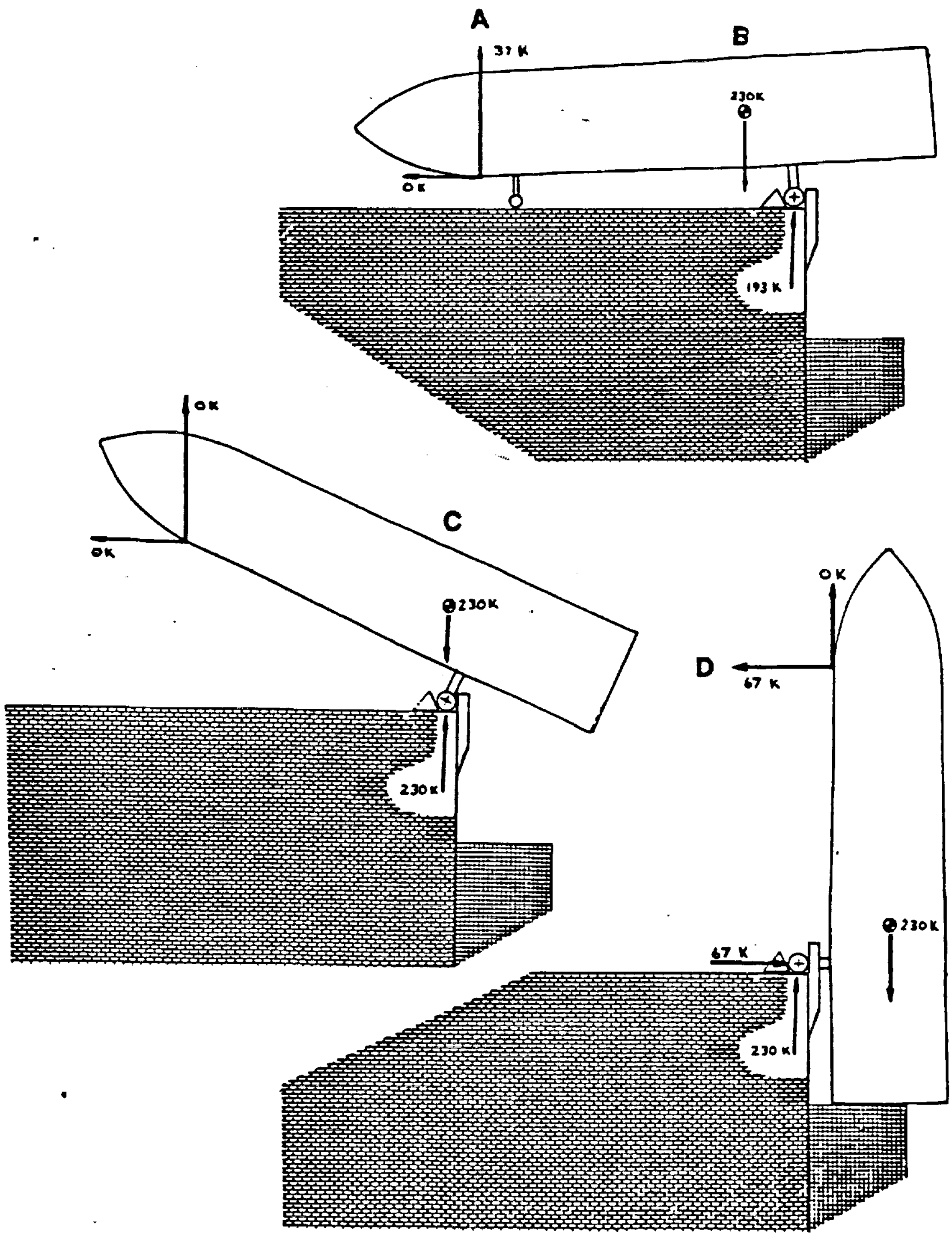


Figure 3.1-4
VEHICLE ROTATION / ERECTION CONCEPT

3.1.3 PROCESSING FLOW EXAMPLE

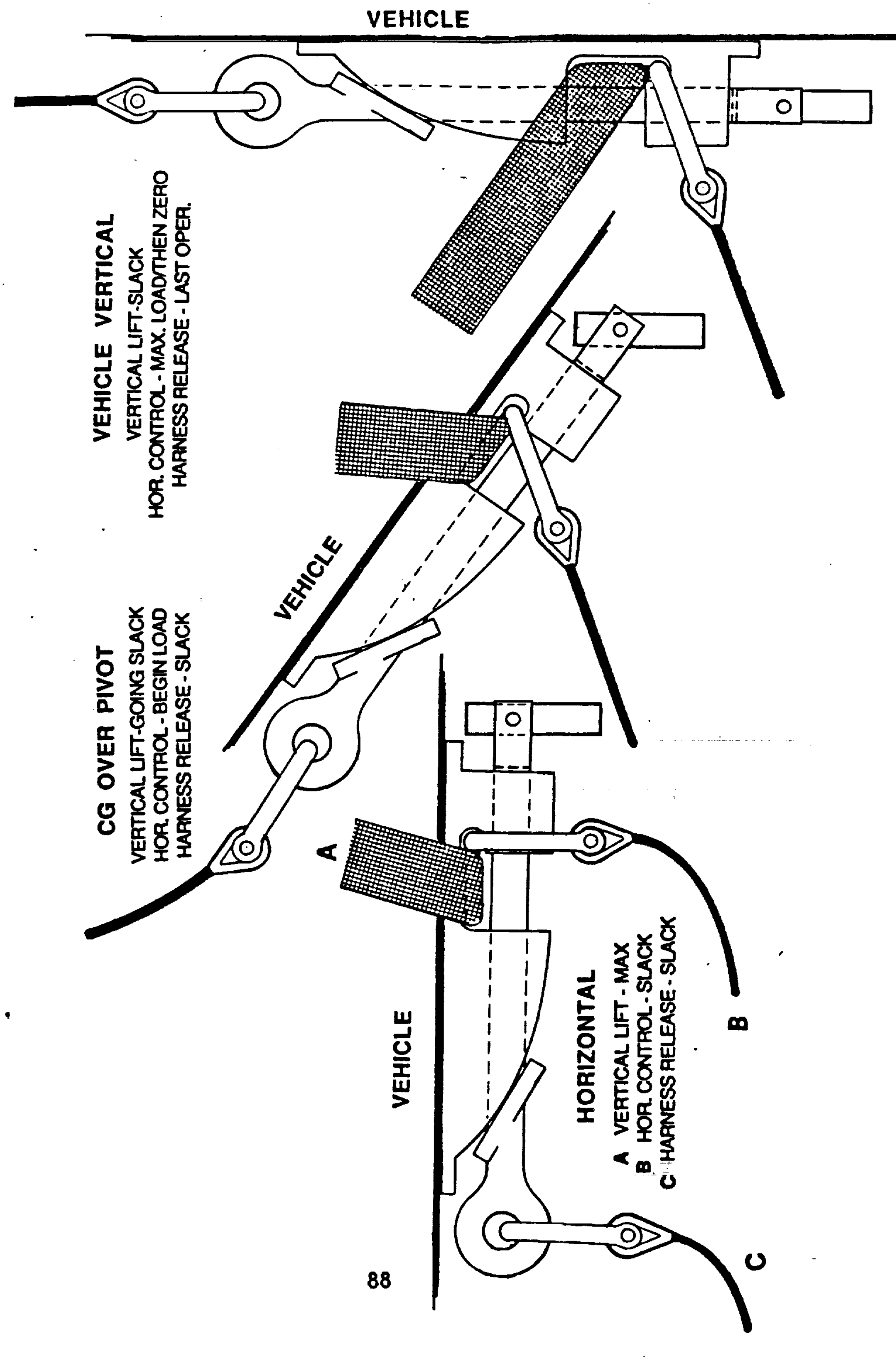


Figure 3.1-5
VEHICLE LIFT FITTING CONCEPT

3.2 OPERATIONS HEADCOUNT/TIME/COST

3.2.1 CIRCA 2000 HEADCOUNT DERIVATION

This section begins by presenting a brief summary of KSC overall headcount during September 1985; showing a total of about 16,000 persons, 70% of which were contractor employees. We then derive a matured Circa 2000 (C2K) program headcount by analyzing the April 1986 STS/SPC contract work breakdown structure (WBS) in relation to ground processing and system requirements of the C2K concept. The C2K result, as shown herein, is a projected SPC-equivalent headcount of 2246 persons, 38% of SPC, November 1985.

Note: 1985 Shuttle Processing Contractor headcount is used as baseline since it is the time period most representative of normal STS processing (4 vehicles, 8 flights per year).

3.2.1.A 1985 KSC HEADCOUNT SUMMARY

The following is a tabulation of KSC population during September 1985. Source for the data was NASA KSC Manpower and Organization Office.

HEADCOUNT SUMMARY

Contractor	11,055
Construction	440
Tenants	2,492
Civil Service	2,080
TOTAL	16,067

KSC CONTRACTOR BREAKDOWN

Shuttle Contractors (SPC)	6,567
Center Support (BOC)	2,225
Payload Processing (PGOC)	831
Expendable Vehicle	661
R&D Support	744
VAFB	27
TOTAL	11,055

3.2.1.B APPLICATION OF SHUTTLE PROCESSING CONTRACTOR WBS

The following tabulation shows a summary of the STS SPC contractor headcount for November 1985. It is considered representative of STS ground processing manpower during launch preparation of 51-L. The column "C2KHC" is the estimated headcount derived by this study from assessment of the SPC WBS in relation to comparable C2K ground processing and flight systems concepts. The C2K processing headcount worked out to 38% of SPC/51-L. This reduction was a result of the C2K concept having a significantly simpler set of processing facilities, less GSE, simpler flight vehicles, and extensive computerized test-and-checkout and management systems as envisioned in Circa 2000. Appendix A is a detailed look at the WBS, SPC headcount and the rationale/assumptions for C2K headcount estimation.

3.2.1.B APPLICATION OF SHUTTLE PROCESSING CONTRACTOR WBS (Continued)

KSC CONTRACTOR HEADCOUNT

	STS 9/85	STS 11/85	C2K	C2K/STS,%
o Launch Vehicle Ground Processing Contractor (SPC)	6567	5958	2246	37.7
o Center Support (BOC) C2K HC estimated at 50% of STS	2225	*2019	1010	50.0
o Payload Processing (PGOC) C2K HC: 754 + (123 WBS 1.1.5 Cargo Opers) + (20% passenger canister O&M) + (20% autonomous cargo canister O&M)	831	*754	1209	160.3
Sub-total:	9623	8731	4465	51.1
o Expendable Vehicle	661	661	0	
o R&D Support	744	744	0	
o VAFB	27	27	0	
	11,055	10,163	4,465	

* Headcount derived from SPC ratio: Nov 85/Sep 85; assuming that BOC and PGOC were in a similar maturing-program headcount reduction.

Combining the above C2K contractor headcount estimate with the total KSC summary provides:

HEADCOUNT SUMMARY

	STS	C2K
Contractor	11,055	4,465
Construction **	440	0
Tenants **	2,492	0
Civil Service**	2,080	840***
Total:	16,067	5,305

In considering overall launch site cost in relation to headcount, it is necessary to remove the tenant headcount which is not a direct cost to KSC (wildlife, orange growers, certain R&D programs and USAF, etc.). The net result shows C2K total program headcount is 39% (5,305/13,575) of Sept. 1985 KSC headcount.

** Data available for 9/85 only.

*** Civil Service headcount reduced by same factor as contractor, i.e., 4465/11,055 (40%).

3.2.1.B APPLICATION OF SHUTTLE PROCESSING CONTRACTOR WBS (Continued)

These data are believed to provide valuable insight into the existing level of organizational complexity essential to support and process contemporary orbital access systems. That complexity is driven by the high level of vehicle and flight systems complexity and their attendant technical requirements in assuring the highest practical level of management control and operational safety and reliability. The net conclusion here is a plea for much greater simplicity in future launch vehicles to minimize quantity and complexity of systems to allow the very minimum in repetitive ground processing operations and maintenance.

CIRCA 2000 HEADCOUNT SUMMARY

STSWBS		STSHC	*C2KHC	C2K/STS%
1.1	Shuttle Processing	2,041	820	40.2
1.2	Processing Engrg.	362	181	50.0
1.3	Facility Opers. & Maint.	783	306	39.1
1.4	LPS O&M/Inst. Measurements & Cals.	548	165	30.1
1.5	Facility/Support Eqpt. Engr.	101	26	25.7
1.6	Program Support	581	146	25.1
1.7	Program Mgmt.	662	341	51.5
1.8	Production 2nd Line Facs.	323	0	0
1.9	Communications	223	148	66.3
1.10	DOD Support	172	86	49.9
1.11	Marshall Booster Assy. Contract	12	0	0
1.12	Cargo Support	35	4	11.3
1.13	Centaur Project	69	0	0
1.14	Uniquely Funded Opers.	8	4	50.0
3.0	Specially Negotiated Projects at KSC	38	19	49.7
Total:		5,958	2,246	37.7% aver.

* C2K headcount derived from summation of Appendix A headcount/WBS comparison

Flight vehicle processing takes the lion's share of headcount and is of specific interest to those interested in vehicle design. The following is a summarized extract from the details of Appendix A and shows headcount breakdown to the third level of WBS. Each third-level item includes up to nine semi-repetitive fourth-level items such as:

- o Vehicle Maintenance
- o Processing Operations
- o Shop Operations
- o Modifications
- o Contingency Operations
- o Support Equipment Maintenance
- o Management Support
- o Receiving Operations
- o Retrieval and Disassembly Operations
- o Stacking Operations
- o Integrated Vehicle Support
- o Cargo Operations

3.2.1.C CIRCA 2000 HEADCOUNT ANALYSIS

The following summarizes the total C2K launch site headcount estimate derived from the rationale and assumptions as noted. This represents a launch site program similar in concept and structure to KSC. The C2K headcount stands alone and is not constrained to a KSC location (see ground rules and assumptions).

VEHICLE PROCESSING THIRD LEVEL WBS HEADCOUNT SUMMARY

WBS		STSHC	C2KHC*
1.1.1	Orbiter Operations	1105	613
1.1.2	SRB Operations	195	0
1.1.3	External Tank Operations	80	0
1.1.4	Launch Operations	523	193
1.1.5	Cargo Operations	137	14
	Total	2040	820

* Includes allowances for C2K booster

3.2.2 CIRCA 2000 GROUND PROCESSING TIME ESTIMATION

This section begins with a presentation of historical ground processing timeline data, both idealized goal and actual. This shows that actual ground processing operations for the 25th launch required over 5600 hours of support processes. This is an 18.7 growth factor over the original Level I guideline of 300 total processing hours (160-hr turnaround).

The C2K ground processing timeline is then derived by a comparative analysis of 51-L processes and procedures with C2K-concept facilities, systems, and operations. Details of the comparison and time estimates are shown in Appendix B. The result is a total processing timeline of 1043 hours for C2K. This is 19% (1043/5603) of time required for 51-L.

A concept to reduce the estimated C2K orbiter total processing (series and parallel) timeline from 571 to 195 hours is also shown with the extraordinary conclusion that full implementation of C2K concepts can potentially produce a net launch vehicle turnaround period of 109 hours.

The following tabulation summarizes the processing time exercises presented later in this section and assists in defining the difference between "turnaround" and "processing" time.

Vehicle	Turnaround (hrs)	Processing time (total hours)
STS Level I (design goal)	160	300
STS 51-L (actual)	1368	5604
C2K Orbiter		544
Booster		472
Integrated		27
Total of individual Timelines		1043
C2K (154-hr turnaround) [all processes, except E & F, contain parallel workload assessments]	154	363
C2K (109-hr turnaround) [all processes contain parallel workload assessments; item G assumes dual crews or dual parallel work]	109	195

3.2.2.A 51-L BASELINE

(Ref.: Shuttle Ground Operations Efficiencies/Technologies Study, Final Report, Volume 2, May 4, 1987)

STS OPERATIONS ANALYSIS

FUNCTION	160- HR TURNAROUND GUIDELINE, CLOCK HOURS	TOTAL HRS. ACTUALLY EXPENDED, CLOCK HOURS
A. LANDING AREA	1.0	10.5
B. SAFING & DESERVICING	8.0	416.5
C. PAYLOAD REMOVAL PREPS	5.0	25.0
D. MISSION UNIQUE PAYLOAD EQPT. REMOVAL/INSTL.	27.0	429.5
E. ORBITER SCHED. MAINT.	24.0	1132.5
F. PROP. SYSTEM SCHED. MAINT.	24.0	893.0
G. UNSCHED. MAINT. & SYS. VERIF.	50.0	753.5
H. TPS REFURB.	40.0	191.0+
I. ORBITER INTEGRATED TEST	10.0	DELETED FROM OMRSD
J. PREPS. FOR MATING	12.0	359.5
K. TOW ORBITER TO VAB	.0	.5
L. TRANSFER AISLE ORB. PREMATE OPS.	5.0	18.5
M. ORBITER MATE & INTERFACE VERIF.	15.0	144.0
N. SHUTTLE I/F TEST	19.0	DELETED FROM OMRSD
O. MOVE TO PAD	7.0	13.5
P. MLP MATE TO PAD & LAUNCH PAD VAL	3.0	39.5
Q. PAYLOAD IN PCR	13.0	174.0
R. FUEL CELL DEWAR LOADING	10.0	6.5
S. SHUTTLE LAUNCH READINESS VERIF.	6.5	57.5
T. P/L INST. & LAUNCH READINESS VERIF.	9.0	273.5
U. CLOSEOUT	1.0	NONE ALLOCATED
V. HAZARDOUS SERVICING/SERVICE. DISC.	8.5	543.5
W. LAUNCH FROM STANDBY	2.0	121.5
TOTAL	300.0	5,603.5

This is the 160-hr turnaround goal for STS. The hours are clock hours. The total 300.0 hours for the 160-hr. turnaround includes all major activities, both serial and parallel. Level I directed that the Shuttle be designed so that it could be launched within 160 working hours after landing of the previous mission. This would be on a two-shift workday, five-days a week. Level II then divided this 160-hrs into time to be spent in the OPF, VAB, and at the Pad. All designs were to support these requirements, but due to vehicle and ground operations complexity, the actual operation times have been lengthened by over an order of magnitude. Figure 3.2-1 is the original Level II Schedule with the time allotted to perform each task. Following are sheets giving the 51-L comparison.

Letters A through W are used for each operation identified on the Level II Schedule. The title of the block on the original schedule, with time originally allocated, is used for the heading. A list of the actual operations, with timelines, will show what was required (by the OMRSD, equipment failure, repair and retest) to process 51-L.

160-HR TURNAROUND GOAL

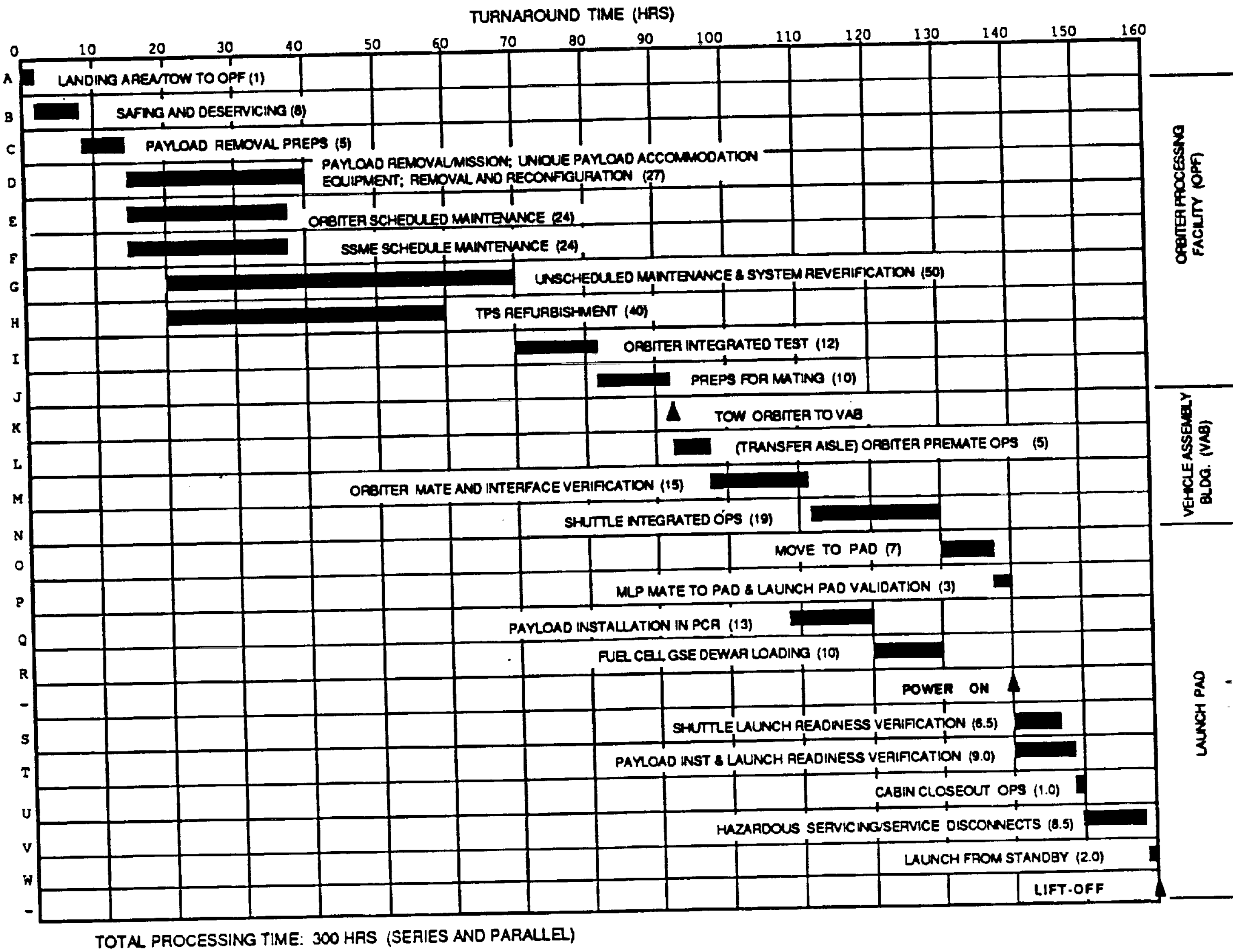


Figure 3.2-1
STS 160-HR TURNAROUND GOAL
(PAYLOAD INSTALLATION AT PAD)

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3.2.2.B DERIVATION OF C2K TIMELINE FROM 51-L TIMELINE

Total C2K ground operations support timeline is estimated at 1043 clock hours (both series and parallel) which is 19% of the equivalent expended on 51-L. In light of very extensive OMRSD requirements for the management and control of KSC/STS launch operations, this can be considered as a phenomenal reduction. The estimates for hours were derived by an equivalence assessment/comparison of the major WADs used for processing 51-L. Appendix B presents those WADs by number, title, 51-L clock hours for accomplishment, and a few of the assumptions and rationale used to develop the C2K equivalent flow time. The reduced flow time is highly dependent on 1) a very comprehensive automated, computerized flight vehicle self-test and status reporting system; 2) grossly simpler and less quantity of vehicle systems than STS; and 3) a greatly simplified/reduced support facilities and GSE scenario.

	FUNCTION	160 HR TURNAROUND GUIDELINES	51-L TOTAL HRS EXPENDED	C2K POTENTIAL TOTAL HRS. ORB......		......BSTER
A.	LANDING AREA	1.0	10.5	2	I	2
B.	SAFING & DESERVICING	8.0	416.5	21	N	21
C.	PAYLOAD REMOVAL PREPS	5.0	25.0	4	T	0
D.	MISSION UNIQUE PAYLOAD ACCOM. EQPT. REMOVAL/INST.	27.0	429.5	0	E G	0
E.	ORBITER SCHED. MAINT.	24.0	1132.5	98	R	60
F.	PROP. SYS. SCHED. MAINT.	24.0	893.0	97	A	97
G.	UNSCHED. MAINT. & SYS. VERIF.	50.0	753.5	260	T	260
H.	TPS REFURBISHMENT	40.0	191.0+	20	E	0
I.	ORB. INTEGRATED TEST	12.0	DELETED	0	D	0
J.	PREPS. FOR MATING	10.0	359.5	34		26
K.	TOW ORBITER TO VAB	0	.5	0	V	0
L.	TRANSFER AISLE ORB. PREMATE OPS.	5.0	18.5	0	E H.	0
M.	ORB. MATE & INTERFACE VERIF.	15.0	144.0	0		0
N.	SHUTTLE I/F TEST	19.0	DELETED	0		0
O.	MOVE TO PAD	7.0	13.5	6		6
P.	MLP MATE TO PAD & PAD VAL.	3.0	39.5	*	4	*
Q.	P/L INSERTION IN PCR	13.0	174.0	0		0
R.	FUEL CELL DEWAR LOADING	10.0	6.5	0		0
S.	SHUTTLE LAUNCH READINESS VERIFICATION	6.5	57.5	*	1	*
T.	P/L INST. & LAUNCH READINESS VERIF.	9.0	273.5	*	7	*
U.	CABIN CLOSEOUT	1.0	NON-ALLOTTED	2		0
V.	HAZARDOUS SERVICING/SERV. DISCONNECT	8.5	543.5	*	13	*
W.	LAUNCH FROM STANDBY	2.0	121.5	*	2	*
	SUBTOTAL:			544	27	472
	TOTAL:	300.0	5,603.5		1043	

* Not applicable

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3.2.2.C CIRCA 2000 PROCESSING SUMMARY

A review of the 51-L "as-run" barchart data, in conjunction with further study of the above 51-L and C2K timelines provided some interesting observations.

51-L required 57 working days (3 shifts/day) to reach start of launch countdown. Countdown has been eliminated from the following discussion because the two 51-L launch scrubs and related delay are not a valid consideration of required ground processing time. Those 57 days equate to 171 shifts or 1368 clock hours. This time period, when compared to the 5482 total 51-L hours (5603.5 less countdown), indicates an average of 4.0 processes/WADs in work at all times (5482/1368). Applying this value as a first approximation to the C2K orbiter timeline of 569 hours (544 + 27 -2) loads to the conclusion that C2K (in a KSC/STS-similar processing scenario) might represent a series timeline of 142 clock hours (569/4). In comparison to the equivalent 51-L timeline of 1368 hours this indicates C2K might require about 11% as much series processing time as 51-L.

In further assessing this remarkable possibility, each related STS processing item (A through W) was examined with respect to C2K-applicable WADs and further estimation of timeline impact. The WADs and timeline data are presented in Appendix B. Table 3.2-1, "C2K Total Processing Time Summary", indicates the possibility of a further reduction in estimated C2K serial processing time from 142 hours to 109 hours. The tabulation includes critical rationale assumptions related to management of the WAD sequence and workforce to provide a comprehensive level of parallel processes. Figure 3.2-2 is a barchart of the resulting estimated 109-hour C2K processing timeline. It is important to note the 109-hour timeline is developed from a critical assessment of STS-related WADs, not from the 160-hour timeline of Figure 3.2-1.

The above discussion has addressed the C2K orbiter as the maximum timeline constraint. The booster was shown herein to require 499 hours (472 + 27) as compared to 571 (544 + 27) for the orbiter. Individual stage processing would, of course, occur in parallel and accommodate the 109-hour turnaround.

C2K PROCESSING TIME SUMMARY

STS OPER.	C2K TOTAL HRS ORB.		BSTR	109-HR TURNAROUND	BARCHART RATIONALE (PARALLEL WORK REQUIRED)
A	2		2	2	- - - - -
B	21		21	8	Enter OPF/jack & level - 1 hr +; safing patches/MMU -1 hr; power & propulsion (3 items parallel) - 6 hr; (serial operations)
C	4		0	4	- - - - -
E	98		60	38	Electrical/electronic - 36 hrs; mech A/F -38 hr; Insp./fluids/propulsion - 24 hr; (parallel opers.)
F	97		97	36	Heat shields/nozzle insp. - 36 hr; engine L&F/ pumps - 32 hr; MPS - 29 hrs; (parallel opers.)
G	260		260	48	Elec. pwr. - 95 hr; electronics - 44 hr; mech. A/F - 36 hr; propulsion - 85 hr; (power & propulsion required dual crews working in parallel)
H	20		0	20	- - - - -
J	34		26	14	Mech. A/F preps - 10 hr; P/L act. - 8 hr; orb. closeout - 14 hrs; (parallel opers.)
O	6		6	6	- - - - -
P	*	4	*	2	Pad valid. - 2 hr; power preps - 2 hr; (parallel)
S	*	1	1	1	- - - -
T	*	7	*	4	CDDT - 4 hr; other preps 3 hrs in parallel; no propellant load
** V	*	13	*	8	Propellant load 8 hr; other preps 3 hr in parallel; blanking plate to T-2 hr
U	2		0	2	- - - - -
W	*	2	*	2	- - - - -
SUB-TOTAL	544	27	472		
TOTAL		1043		195 SERIES AND PARALLEL	

* Integrated vehicle timeline
** C2K sequence reversed

Table 3.2-1
C2K TOTAL PROCESSING TIME SUMMARY

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3.2.3 OPERATIONS COST

This section begins with a brief tabulation of actual NASA-wide FY85 STS program recurring costs. The data show that STS cost/pound-to-orbit for the 8 launches was nearly $5,500/lb: The concluding portion presents a simple C2K program recurring cost estimate using the launch operations headcount/cost factor developed in this study. In conclusion it appears theoretically possible for the C2K vehicle and ground processing concept to achieve 24 launches/year with a payload cost-to-LEO 11% of STS.

3.2.3.A NASA AND KSC OPERATIONS COST FOR FY85

The following are brief tabulations of NASA-wide STS program actual costs for FY85 leading to the conclusion that payload cost-to-orbit for the 8 flights of FY85 was nearly $5500/lb. This high cost is the driving factor to reduce costs by a factor of ten.

STS RECURRING COSTS
FY85 Total (Actuals)

HARDWARE	FY85 COST, M$	% OF TOTAL
SRB	464.2	21.2
ET	415.8	19.0
GSE	24.1	1.1
Orbiter Hardware	162.6	7.4
Crew Equipment	36.3	1.7
Subtotal	1,103.0	50.4
PROPELLANTS	30.3	1.4
OPERATIONS		
Launch Operations	347.5	15.9
Flight Operations	345.3	15.8
SSME	51.6	2.3
Contract Admin.	17.1	0.8
Network Support	20.4	0.9
R&PM	274.2	12.5
Subtotal	1,056.1	48.2

Total $2,189.4M
Cost per flight (8) 2189.4/8 = $273.7M
Cost-to-Orbit (50K lb/flight) = $5,474/lb

Data Reference: Congressional Budget Office

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3.2.3.B CIRCA 2000 PROJECTIONS

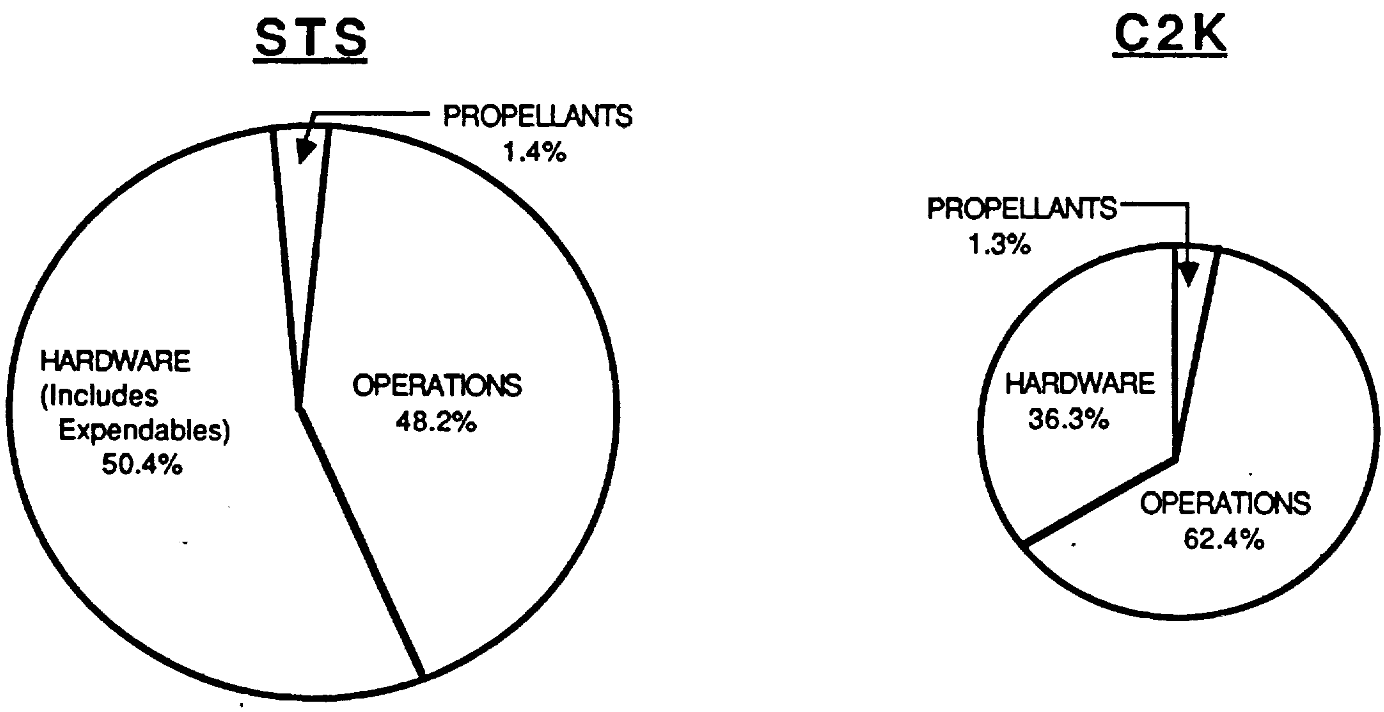
The following is a simple, first order estimation of C2K total program recurring costs. The estimates are derived by comparison to STS. The fractions and factors are noted. The .39 factor for launch operations is one of the prime results of this study and is based on the C2K-equivalent KSC headcount of .39 shown in section 3.2.1.B. Figure 3.2-3 shows the net cost relationships of STS and the C2K concept.

C2K RECURRING COSTS
Derivation by STS Comparison

Note: C2K ground processing requires less than 2 weeks, easily allowing 24 launches/year.

		STS FY85$ M$	C2K FY85$ M$	
STS HARDWARE				
SRB		464.2	0	
ET		415.8	0	
GSE		24.1	12.0	(STS x .5)
Orbiter Hardware		162.6	122.0	(STS x .25 x triple STS flights)
Crew Equipment		36.3	36.3	
Booster Hardware		0	91.5	(C2K Orbiter x .75)
		------	------	
Subtotal		1,103.0	261.8	
PROPELLANTS		30.3	9.1	(STS X .05 X 2 vehicles x triple STS flights; O_2/HC propellants)
OPERATIONS				
Launch Operations		347.5	135.5	(STS x .39)
Flight Operations		345.3	120.9	(STS x .35)
SSME		51.6	31.0	(STS x .1 x 2 vehicles x triple STS flights)
Contract Admin.		17.1	8.6	(STS x .5)
Network Support		20.4	13.7	(STS x .67)
R&PM		274.2	137.1	(STS x .5)
		-----	-----	
Subtotal		1,056.1	446.8	
Total		$2,189.4M	$717.7M	
Cost per flight	(8)	$273.7M	$29.9	(24)
Cost/lb to orbit				
o 50K - LEO		$5474		
o 20K - SS			$1495	(28% STS)
o 50K - LEO			$ 598	(11% STS)

RECURRING COSTS



	STS	C2K
TOTAL ANNUAL RECURRING COSTS, M$	2189.4	717.7
RECURRING COST/FLIGHT, M$	273.7 (8)	29.9 (24)
COST/LB-TO-ORBIT, $; 50K LB. LEO	5474	598 (11% STS)
20K LB SS		1495 (28% STS)

Figure 3.2-3
Recurring Cost Relationships

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APPENDIX A

C2K GROUND PROCESSING HEADCOUNT ESTIMATION BY APPLICATION OF STS WBS

Notes:

1. The STS SPC work breakdown structure numbers and titles are tabulated under column "STS WBS" and are taken from KSC WBS Dictionary, LS0000033-1822, dated April 1, 1986.

2. The STS SPC headcount in November 1985 is tabulated under column "STSHC" and is considered representative of ground processing activities during processing of 51-L.

3. Estimated C2K headcount is presented in the "C2KHC" column and was estimated by an equivalence assessment/comparison with actual 51-L processing activities, i.e., the C2K processing scenario is assumed basically equivalent with methods, processes, and procedures utilized at KSC to meet NASA and DOD systems management requirements, OMRSDs, etc.

HEADCOUNT SUMMARY

STS WBS		STSHC	C2KHC
1.1	Shuttle Processing	2040.1	820
1.2	Process Engineering	361.7	181
1.3	Facilities Operations and Maintenance	783.2	306
1.4	LPS O&M/Inst. Measurements and Calibration	547.5	165
1.5	Facility/Support Equipment Engineering	101.3	26
1.6	Program Support	581.4	146
1.7	Program Management	662.1	341
1.8	Production - 2nd Line Facilities	323.1	0
1.9	Communications	223.2	148
1.10	DoD Support	172.4	86
1.11	Marshall Booster Assembly Contract	12.3	0
1.12	Cargo Support	35.3	4
1.13	Centaur Project	68.6	0
1.14	Uniquely Funded Operations	8.0	4
3.0	Specially Negotiated Projects at KSC	38.2	19
		5,958.4	2,246

2246/5958.4 = .377

See 3.2.1.B for total headcount derivation

APPENDIX A
C2K GROUND PROCESSING HEADCOUNT ESTIMATION BY APPLICATION OF STS WBS

WBS Level 3		STSHC
1.1.1	Orbiter Opers.	1105.2
1.1.2	SRB Operations	195.5
1.1.3	ET Operations	80.1
1.1.4	Launch Operations	522.7
1.1.5	Cargo Operations	136.6
1.2.1	Engineering Svs.	47.4
1.2.2	Test Eng. Spt.	19.9
1.2.3	LPS Eng. & S/W Dev.	294.4
1.3.1	Facility O&M Spt.	207.7
1.3.2	OPF	34.9
1.3.3	HMF	5.6
1.3.4	VAB	72.1
1.3.5	LCC	11.2
1.3.6	MLP	25.4
1.3.7	C/T	25.0
1.3.8	Pad A	121.8
1.3.9	Pad B	0
1.3.10	SLF	13.5
1.3.11	Sec. Landing Sites	2.4
1.3.12	CLS	2.6
1.3.13	Hangar AF	33.8
1.3.14	SRB Retrieval Vessels	20.0
1.3.15	Parachute Fac.	0
1.3.16	Comm. Dist & Switching Center	0.9
1.3.17	LETF	0.1
1.3.18	Logistics Fac.	8.8
1.3.19	Shops & Labs	105.5
1.3.20	Heavy Eqpt.	18.9
1.3.21	Mechanical	17.3
1.3.22	Low Voltage Elec.	15.1
1.3.23	Institutional Maint.	11.1
1.3.24	Cranes/Doors/ Platforms/Elevators	2.2
1.3.25	Pneumatics Sys.	1.0
1.3.26	Opers. Shop Mtn.	1.9
1.3.27	Maint. Serv. Contracts	0
1.3.28	Processing of Storage Facilities (PSF)	23.2
1.3.29	Miscellaneous Facs.	4.1
1.4.1	LPS O&M	302.6
1.4.2	LPS Maint. and Support Engineering	73.0
1.4.3	Instrumentation Measurement & Calib.	103.2
1.4.4	Integ. Ground Opers. Support	68.8
1.4.5	LPS Measurment and Calib. Mgmt./Support	0
1.5.1	Support Engrg. Mgmt. & Control	7.2

WBS Level 3		STSHC
1.5.2	Support Eng.	58.5
1.5.3	Configuration Mgmt.	7.8
1.5.4	Special Eng. Proj.	27.8
1.6.1	SR & QA	152.1
1.6.2	Logistics	403.5
1.6.3	Info. & Data Mgmt.	25.9
1.7.1	General Mgmt.	248.8
1.7.2	Program Controls	65.8
1.7.3	Finance & Contracts	58.8
1.7.4	Human Resources	78.4
1.7.5	Operations Mgmt.	75.3
1.7.6	Training	71.8
1.7.7	SPDMS	35.5
1.7.8	LMIS	21.1
1.7.9	Work Control Sys.	36.5
1.7.10	Temp. Opers. Spt.	0
1.8.1	Pad B	142.6
1.8.2	MLP3	2.1
1.8.3	Shuttle Improvements	26.6
1.8.4	LPS	0
1.8.5	Spares	2.6
1.8.6	CLS	5.9
1.8.7	Pad B/MLP#3 Early Turnover	135.7
1.9.1	Voice Comm.	88.6
1.9.2	Wideland Trans. & Nav. Aid	68.0
1.9.3	Support Services	57.2
1.9.4	Comm. Planning and Requirements	9.5
1.10.1	VLS Opers. Support	55.2
1.10.2	VLPS Support	13.2
1.10.4	Logistics	4.0
1.10.5	Software	5.8
1.10.6	Orbiter Func. Sim. (OFS)	0.8
1.10.7	Training	2.0
1.10.8	KSC DoD Security	85.9
1.11.0	MBAC Support	0
1.11.1	CCMS Maint.	10.5
1.11.2	Software Maint.	0
1.11.3	Fac., Sys. & Support Eqpt.	1.6
1.11.4	Logistics	0
1.12.1	CITE & OFS Support	14.4
1.12.2	Comm.	11.9
1.12.3	Site Support	5.3
1.12.4	Cargo Optional Svc.	3.7

APPENDIX A
C2K GROUND PROCESSING HEADCOUNT ESTIMATION BY APPLICATION OF STS WBS

STS WBS		STSHC	C2KHC	△
1.1	Shuttle Processing	2040.1	820	-1220.1
1.1.1	Orbiter Operations	1105.2	613	-492.2
1.1.1.1	Orbiter Maintenance	498.1	145	-353.1
	(C2K Booster Maintenance)	0	138	+138

Rationale: Scope covers all routine orbiter maintenance performed in the OPF except TPS tile. Includes SSME, OMS and RCS pods, forward RCS (HMF activities), electrical, mechanical, physical, electronic, optical, in-place cals, etc. C2K has no hypergols, no APU, no hydraulics, durable TPS, no ammonia boiler, remote/auto flight control, designed for systems/component access, cargo and passenger canister support is offline with extensive computerized self-test and status reporting BITE.

The WAD analysis (Appendix B) for:

E. Orbiter Scheduled Maintenance
F. Propulsion Systems Scheduled Maintenance
G. Unscheduled Maintenance and System Reverification indicates the following STS-related work loads:

	51-L WADs	51-L HOURS	C2K ORB WADs	C2K ORB HOURS	C2K BSTR WADs	C2K BSTR HOURS
E	52	1132.5	28	98	18	60
F	17	893	10	97	10	97
G	37	753.5	28	260	28	260
Total:	106	2779	66	455	56	417

The reduction in WADs and hours estimated for C2K is the result of reduced quantities of flight systems and GSE, computerized self-test, design-for-accessibility and reduced maintenance. Net C2K work percentages of related 51-L work are:

	WADs	HOURS
C2K ORB	66/106 = 62.3%	455/1862.5 = 24.4%
C2K BSTR	56/106 = 52.8%	417/1688.5 = 24.7%

As seen above C2K retains over half the related STS WADs, but reduces the equivalent timeline to about 25%; an apparently contradictory situation that requires further assessment.

1.1.1.1 (Continued)

In examining the 51-L WADs not needed by C2K, the 51-L hours thus affected are:

	51-L WADs	ELIMINATED 51-L WADs		51-L HOURS	(C2K ORB) ELIMINATED 51-L HRS.	(C2K BSTR) ELIMINATED 51-L HRS.
E.	52	24		1132.5	650.5	824.5
F.	17	7		893	86.5	86.5
G.	37	9		753.5	179.5	179.5
			TOTAL:	2779	916.5	1090.5

This indicates that 33% (916.5/2779) of the STS-related hours have been eliminated by the C2K orbiter concept. In assuming a constant 51-L headcount and utilization factor throughout the processing cycle, a 33% reduction in headcount is justified for this comparison. In reality some O&M-intense systems eliminated by C2K (hydraulics, APU, et al) will require alternate, less complex, systems. An estimated one-third * of that 33% reduction is therefore returned, resulting in a net effective decrease of 22%.

The remaining workload required by C2K (78% of 51-L) can be performed quicker and more simply than 51-L in accord with above noted simplifications. The following estimates account for that increased efficiency assuming the headcount is approximately divided into electrical-electronic/ mechanical-airframe/ propulsion (about 1/3 each).

ELEC (.78)(.33)(.5, extv. computer test)(.8, easier access) = .103
MECH (.78)(.33)(.8, less O&M required)(.7, easier access) = .144
PROP (.78)(.33)(.3, less O&M required)(.5, easier access) = .039

TOTAL: .286

These assumptions lead to the conclusion that C2K orbiter headcount for performing WBS 1.1.1.1 (E,F, and G) can be about 29% of 51-L.

(498) (.29) = 145 people

Applying the above logic to the C2K booster produces the following:

1090.5/2779 = 39% reduction in STS-related workload
.39 - .13* new simpler replacement systems = .26 net workload factor

This indicates a basic reduction in STS-related workload of 26% for the C2K booster (compared to 22% for the C2K orbiter). C2K booster headcount is:

(.74/.78) 145 = 138 people for C2K booster

*Compensating replacement of "old systems" with simpler systems.

1.1.1.1 (Continued)

Further conclusions can be drawn relative to process efficiency. The above numbers indicate electrical work to require 40% of related 51-L effort; Mechanical work 56%; and Propulsion work 15% of 51-L. These assumptions are critical and highly sensitive on estimated workload and headcount for WBS 1.1.1.1.

Unaddressed, as yet, is the earlier mentioned contradiction wherein C2K retains over half the WADs, but estimates processing timelines of about 25% of the related 51-L timeline. A further consideration, based on the above assessments, is that basic C2K orbiter workload is 78% of 51-L, i.e., 22% of 51-L hours are eliminated by the C2K concept. And still further we have shown the 78% remaining workload requires only 29% of the equivalent 51-L hours in accord with proposed simplicity and increased efficiencies.

Thus, the combined effects of reduced basic workload (.78, less systems) and increased efficiency (.29, simpler systems) produces a net timeline reduction to 23% of 51-L (.78) (.29). This is in close agreement with the C2K orbiter hours estimated at 24.4% of 51-L.

WBS	WBS	STSHC	C2KHC	Δ
1.1.1.2	Orbiter Shop Operations	73.0	146	+73

Rationale: STS scope includes 17 shops, battery, optical, calibraton, wheel/tire, etc. It is assumed that C2K decreases in ordnance and hydraulics, etc., will be offset by increases in battery, power supply, wheel/tire, communications, tracking, etc. A 100% increase in workload is estimated to accommodate C2K orbiters and boosters.

1.1.1.3	Orbiter Mods	41.5	42	+.5

Rationale: STS scope includes on-line assessment, installation, validation, and emergency field engineering changes for orbiter mods. C2K is a much simpler vehicle, having easier access designed-in. C2K is not piloted/manned and nearly half of orbiter mods are to meet crew requirements. The tradeoff between simpler C2K vehicles and the need to support orbiter and booster leads to a workload estimate equal to STS.

1.1.1.4	Orbiter Contingency Operations	0	0	0

Rationale: STS scope is the performance of unplanned contingency operations either at CLS or rollback to OPF.

1.1.1.5	Orbiter SE Maintenance	47.5	10	-37.5

Rationale: Scope covers effort to maintain SE that interfaces with the orbiter during flight. Nearly all such SE is for manned operaton. C2K requirement estimated at 20% STS.

APPENDIX A

C2K GROUND PROCESSING HEADCOUNT ESTIMATION BY APPLICATION OF STS WBS

STS WBS		STSHC	C2KHC	△
1.1.1.6	Orbiter Processing Mgmt/Support	273.6	96	-177.6

Rationale: Scope covers general management and supervision of orbiter processing crews, general administration, readiness reviews, SR&QA management, mission planning, scheduling, and work control. C2K has 2/3 of STS major vehicle components (orbiter/booster vs. orbiter/ET/SRB) less than 1/2 of STS GSE, about 1/3 the headcount, no direct P/L involvement, and a nearly paperless interconnected computer system for planning, scheduling, work control, and status. C2K workload estimated at 35% STS.

1.1.1.7	Orbiter Tile Operations	123.2	12	-111.2

Rationale: STS scope includes maintenance and modification of TPS; repair ferry damage, plan and incorporate mods, replace blankets, tile, thermal barriers, gap fillers, waterproofing compounds, planning/scheduling, OMD development/revision. Rockwell support subcontract excluded (see 1.14.3). C2K requires robust, low maintenance TPS. Workload estimated at 10% of STS for inspection, replacement of any routinely consumed or expended TPS.

1.1.1.8	Orbiter Landing Operations	48.3	24	-24.3

Rationale: Scope includes pre and post-landing operations at SLF and all secondary or CLS. Includes flight related operations, SCA support, SCA demate, RTLS coverage, convoy, planning, transportation, material, rentals, freight, etc. C2K workload estimated at 50% to "share the load" with STS. This represents a potential decrease in STS overhead. The 50% is estimated by a C2K launch rate 3 times greater than STS, offset by vehicles that are much simpler in SLF operational support requirements (no hypergols, no ground power, etc.)

1.1.2	SRB Operations	195.5	0	-195.5

1.1.2.1	SRB Processing Operations	69.8	0	-69.8
.2	SRB Stacking	39.9	0	-39.9
.3	SRB Retrieval Oper. & Disassy.	30.6	0	-30.6
.4	SRB Shop Opers.	13.8	0	-13.8
.5	SRB Modifications	2.9	0	- 2.9
.6	SRB Contingency Opers.	5.4	0	- 5.4
.7	SRB SE Maintenance	1.3	0	- 1.3
.8	SRB Processing Mgmt. Support	32.0	0	-32.0
.9	Processing & Storage Fac. (PSF)	0	0	0

Rationale: C2K has no SRB or equal operations

APPENDIX A

C2K GROUND PROCESSING HEADCOUNT ESTIMATION BY APPLICATION OF STS WBS

WBS	WBS	STSHC	C2KHC	△
1.1.3	External Tank Operations	80.1	0	-80.1
1.1.3.1	ET Receiving Operations	8.1	0	- 8.1
.2	ET Processing Operations	38.3	0	-38.3
.3	ET Shop Operations	5.3	0	- 5.3
.4	ET Modifications	3.0	0	- 3.0
.5	ET Contingency Operations	0	0	0
.6	ET SE Maintenance	1.3	0	- 1.3
.7	ET Processing Mgmt/Support	24.1	0	-24.1

Rationale: C2K has no ET or equal operations.

1.1.4	Launch Operations	522.7	193	-329.7

STS Scope covers capability to plan, control, and perform mating of flight elements at VAB and LC-39 including integrated pre-launch testing/servicing, ordnance storage/transportation/ installation, flight crew support and support to launch.

1.1.4.1	Integrated Vehicle Servicing	23.4	18	- 5.4

Rationale: Scope includes installation of ordnance, propellant loading, pneumatic/electrical/hydraulic/mechanical servicing and vehicle support after mating. C2K has greatly reduced ordnance, double the propellant loading, and 2/3 of the major vehicle components, greatly reduced pneumatics/hydraulic systems. Auto-test, low maintenance is the goal. C2K workload estimated at 75%.

1.1.4.2	Integrated Vehicle Test and Launch Operations	325.7	114	-211.7

Rationale: Scope covers SRB, ET, orbiter mating in VAB and associated closeouts; integrated vehicle interface tests, end-to-end tests, operation of LPS and subsystems for T&CO, control and monitor; flight and launch readiness reviews; cabin closeouts; leak test; final crew checks; countdown and launch; mission-peculiar software building and integrated vehicle tests. Launch common software deleted (WBS 1.2.3). C2K has no VAB scenario (mate at pad), and entire integrated vehicle operations are greatly expedited by expanded computerized T&CO; stable vehicle/mission requirements and reduced software mods. C2K workload estimated at 35%.

1.1.4.3	Reserved	0	0	0
1.1.4.4	Pad Shop Opers.	0	0	0

Rationale: C2K has no pad shops except propellants.

APPENDIX A
C2K GROUND PROCESSING HEADCOUNT ESTIMATION BY APPLICATION OF STS WBS

STS WBS		STSHC	C2KHC	△
1.1.4.5	Integrated Vehicle Mods	0	0	0
1.1.4.6	Integrated Vehicle Contingency Opers.	1.0	1.0	0
1.1.4.7	Int. Vehicle SE Maint.	0	0	0
1.1.4.8	Launch Opers. Mgmt/Support	172.5	60	-112.5

Rationale: Scope covers general management and supervision of processing crews, administration/filing/clerical, support of readiness reviews, SR&QA support, planning/scheduling/work control for launch operations. C2K workload estimated at 35%.

1.1.5	Cargo Operations	136.6	14	-122.6

1.1.5.1	Mission & Cargo Integration	115.0	12	-103.0

Rationale: Scope covers mission and cargo integration, assessment, planning, development, and implementation for specific missions and P/Ls; technical liaison with P/L integration organizations and appropriate design centers; design and readiness reviews; configuration requirements planning/ scheduling; orbiter/ facilities/ GSE configurations; pre-flight work on orbiter flight kits, etc. C2K proposes fully autonomous P/L cocoon/canister with self-contained electrical power, communications/ control/ instrumentation, and environmental control. C2K workload estimated at 10% for coordination and delivery scheduling and download coordination. 1.1.5 headcount deleted here is added to PGOC in later analysis.

1.1.5.2	Reserved	0	0	0
1.1.5.3	Cargo Support Systems	3.9	2	-1.9

Rationale: Scope covers sustaining engineering and non-mission maintenance, mods, and operations of orbiter P/L systems, GSE, and facilities. C2K workload estimated at 50%, reflecting much simpler P/L mode of operation.

APPENDIX A
C2K GROUND PROCESSING HEADCOUNT ESTIMATION BY APPLICATION OF STS WBS

STS WBS		STSHC	C2KHC	△
1.1.5.4	Reserved	0	0	0
1.1.5.5	Cargo Contingency Opers.	0	0	0
1.1.5.6	Cargo Mgmt. Support	17.6	0	-17.6

Rationale: C2K is a delivery system only and does not "manage" significant P/L operations other than insertion and offload.

1.2	Processing Engineering	361.7	181	-180.7

1.2.1	Engineering Services			
1.2.1.1	Documentation Integration	47.4	24	- 23.4

Rationale: C2K "paperless" procedure and work documentation system will utilize extensive computer network. C2K equivalent work estimated at 50% STS.

1.2.2	Test Engineering Support			
1.2.2.2, .2		19.9	10	- 9.9

Rationale: C2K simplified vehicle system, T&CO, GSE and ground support operations estimated to reduce work load to 50% STS.

1.2.3	KSC Launch Processing System (LPS) Engineering and Software Development			
1.2.3.1, .2, .3, .4, .5, .6		294.4	147	-147.4

Rationale: STS scope includes systems engineering, hardware engineering, CDS & CCMS software development and firing room applications. C2K will require similar systems and work, but will have 2 control rooms instead of 4 and will not include VLS support. This is one area where applicable software transfer from STS to C2K might be a significant cost saving. With these assumptions, the equivalent C2K work load is estimated at one-half STS.

1.3	Facility Operations & Maint.	783.2	306	-477.2

Prime Rationale:

- o C2K has 1/2 the quantity of equivalent STS major facilities:

  STS: Pads A, B, VAB, OPF, RPSF, VPF, O&C, HMF (8)
  C2K: 1 barren pad,OPF (4 bays), VPF, O&C, (4)

- o C2K has 2/3 the quantity of major vehicle elements:

  STS: Orbiter, SRBs, ET
  C2K: Orbiter, booster

Fourth level WBS 1.3 contains the following repetetive categories:

1.3.x.1 Facility/Systems/GSE Maintenance
1.3.x.2 Facilitiy/Systems Modifications
1.3.x.3 Reserved
1.3.x.4 Support Equipment Modifications
1.3.x.5 Operations and Test Support

STS WBS		STSHC	C2KHC	Δ
1.3.1	Facility O&M Support Operations			
1.3.1.1	Facility Planning & Utilization	5.7	3	
1.3.1.2	Resource Administration	18.2	9	
		23.9	12	-11.9

Rationale: STS scope includes facilities utilization planning, office configuration, major and minor moves, furniture, office equipment, budgets, cost tracking, etc. C2K has 1/2 of STS facilities.

1.3.1.3	Janitorial Services	1.1	1	-.1

Rationale: STS scope includes management of housekeeping in tech shops, laboratories, Orbiter, ET, SRB, flight crew areas, and SSV T&CO areas. C2K assumed equivalent.

1.3.1.4	Support Opers. Mgmt.	182.7	101	-81.7

Rationale: STS scope includes planning/scheduling and follow-up of O&M tasks; work control system, CCC, and management support to O&M of processing facilities and support equipment. C2K has 1/2 STS facilities. CCC is equivalent to STS; electrical power, HVAC/ECS, firex water, pneumatics, 3-shift - 7 day coverage.

$$(183-20\ \text{CCC})\ (1/2) + 20\ \text{CCC} = 81 + 20 = 101$$

1.3.2	OPF			
1.3.2.1, .2, .4, 5		34.9	35	+.1

Rationale: OPF has 2 bays. C2K will need minimum of 4 bays (2 Orbiter, 2 booster). Simplification of vehicle T&CO (BITE; minimal scheduled power outages) and deletion of hypergols (simpler facility and HVAC/contamination control; area-clear periods eliminated) are estimated to offset doubled facility capacity. C2K estimated equivalent to STS in this area.

APPENDIX A
C2K GROUND PROCESSING HEADCOUNT ESTIMATION BY APPLICATION OF STS WBS

STS WBS		STSHC	C2KHC	Δ
1.3.3	HMF			
1.3.3.1.2, .4, .5		5.5	0	-5.5

Rationale: C2K has no HMF or equivalent facility.

1.3.4	VAB			
1.3.4.1, .2, .4, .5		72.1	0	-72.1

Rationale: C2K has no VAB or equivalent facility. (C2K rotation performed at pad by mobile crane; accounted for in Heavy Equipment WBS 1.3.20)

1.3.5	LCC			
1.3.5.1, .2, .5		11.2	6	-5.2

Rationale: STS LCC has 4 control rooms. C2K will have 2 control rooms and 1/2 the workload.

1.3.6	MLP			
1.3.6.1, .2, .4, .5		25.4	0	-25.4

Rationale: C2K has no MLP. Vehicles towed to pad on integral landing gear.

1.3.7	C/T			
1.3.7.1, .4, .5		24.9	0	-24.9

Rationale: C2K has no C/T. Conventional mobile tug used to tow vehicles to pad (tug accounted in Heavy Equipment WBS 1.3.20)

1.3.8	Pad A			
1.3.8.1, .2, .4, .5		121.8	31	-90.8

Rationale: STS pad maintenance for FSS, RSS, LOX, LH2, MMH, N2O4, lightning arrest system, flame trench, flame deflector, fire water, pad deluge water, sound suppression water, shops, offices, terminal rooms, elevators, restrooms, HVAC/ECS, pneumatics/compressors, interior/ external/perimeter lights, high and low voltage electrical substation/transformers/distribution systems, pressure doors, grounding systems. 8/30 = .27
C2K workload estimated at 25% of STS.

APPENDIX A
C2K GROUND PROCESSING HEADCOUNT ESTIMATION BY APPLICATION OF STS WBS

STS WBS		STSHC	C2KHC	△
1.3.9	Pad B	0	0	0
1.3.10 1.3.10.1,.2,.4,.5	SLF1.3.10.1, .2, .4, .5	13.4	13.	-.4

Rationale: STS scope assumed to include O&M of runway, lights, PAPI/Ball-bar lights, MSBLS, MDD, generators, fences and gates. Arrival and departure and control tower operations excluded. C2K groundrules do not limit site to KSC (STS facilities not shared).

1.3.11	Secondary Landing Sites	2.4	0	-2.4
1.3.12	Contingency Landing Sites	2.6	0	-2.6

Rationale: By C2K maturity, launch rate may approach weekly to bi-weekly. Continued usage of launch site personnel to man CLS or secondary sites on TDY will be an unacceptable burden and financial cost to the launch site contractor during the critical (and very busy) countdown period. It is suggested that USAF may cost-effectively establish a non-civilian team to man/operate electronic landing aides and lights at the selected sites. This would accommodate security-critical payload protection/maintenance, and include any critical orbiter safe and deservicing functions in a more timely manner than presently planned. USAF mobility would be a valuable and cost-effective ingredient.

1.3.13	Hangar AF	33.8	0	-33.8
1.3.14	SRB Retrieval Vessels	20.0	0	-20.0

Rationale: C2K has no SRBs or equivalent work load.

1.3.15	Parachute Facility	0	0	0

Rationale: C2K has no parachute.

1.3.16 1.3.16.5	Communications Distribution & Switching Center (CDSC)	0.1	0	-0.1

Rationale: Negligible support required for C2K.

1.3.17 1.3.17.4	LETF	0.1	0	-0.1

Rationale: Negligible support required for C2K.

APPENDIX A

C2K GROUND PROCESSING HEADCOUNT ESTIMATION BY APPLICATION OF STS WBS

STS WBS		STSHC	C2KHC	Δ
1.3.18	Logistics Facilities			
1.3.18.1, .2, .5		9.7	5	-4.7

Rationale: C2K has 1/2 STS facilities, GSE, FSE, and 2/3 the vehicles. C2K Logistics facilities estimated at 1/2 size and workload of STS.

1.3.19	Shops and Labs			
1.3.19.1	Machine Shop	41.0	20	
1.3.19.2	Assembly and Repair	13.0	6	
1.3.19.3	Corrosion Control	8.9	4	
1.3.19.4	Electrical Shop	7.5	4	
1.3.19.5	Electronic Shop	5.2	3	
1.3.19.6	Decontam/Cleaning/ Refurb/Sampling	1.1	1	
1.3.19.7	Comm. Shop	26.2	13	
1.3.19.8	Pneumatics Shop	2.5	2	
		105.4	53	-52.4

Rationale: STS scope is for fabrication, modifications, and refurbishment support of Shuttle processing. C2K has 1/2 facilities, GSE, and simplified vehicle C2K workload estimated at 1/2.

1.3.20	Heavy Equipment			
1.3.20.1, .5		18.9	21	+2.1

Rationale: Headcount for tug vehicles, rollout, and additional mobile crane workload for vehicle rotation at pad estimated at 2 manyears/year.

1.3.21	Mechanical			
1.3.21.1, .5		17.3	9	-8.3

Rationale: C2K has 1/2 facilities and 1/2 GSE.

1.3.22	Low voltage electrical			
1.3.22.1, .2, .5		15.1	8	-7.1

Rationale: C2K has 1/2 facilities, 1/2 GSE, and has no CLS TDY support requirement.

WBS WBS		**STSHC**	**C2KHC**	**Δ**
1.3.23	Institutional Maintenance			
1.3.23.1, .2		11.1	6	-5.1

Rationale: STS scope includes general maintenance and crew quarters maintenance. C2K has 1/2 facilities of STS.

1.3.24	Cranes/Doors/Platforms/Elevators (CDPE)			
1.3.24.1		2.2	0	-2.2

Rationale: C2K has no CDPE shop equivalent to STS VAB operation.

1.3.25	Pneumatics Systems			
1.3.25.1, .5		1.0	1	0

Rationale: Minimum maintenance HC for pneumatics shop.

1.3.26	Operations Shop Maintenance			
1.3.26.1		1.9	2	+.1

Rationale: STS scope includes maintenance and repair of equipment at 21 shops and labs. New C2K equivalent shops and labs can be expected to require equal workload.

1.3.27	Maintenance Serv. Contracts	0	0	0
1.3.28	Processing & Storage Facility (PSF)			
1.3.28.1, .4, .5		23.2	0	-23.2

Rationale: C2K has no PSF or equal facility.

1.3.29	Miscellaneous Facilities			
1.3.29.1, .2, .4		4.1	2	-2.1

Rationale: C2K will have 1/2 of STS facilities.

APPENDIX A
C2K GROUND PROCESSING HEADCOUNT ESTIMATION BY APPLICATION OF STS WBS

STS WBS		STSHC	C2KHC	Δ
1.4	LPS O&M/Inst., Measurements and Calibration	547.5	165	-382.5

1.4.1	LPS O&M			
1.4.1.1	CCMS O&M	161.4		
1.4.1.2	CDS Operations	94.6		
1.4.1.3	RPS O&M	38.8		
1.4.1.4	CCMS Mods	5.9		
1.4.1.5	CDS Mods	0.4		
1.4.1.6	RPS Mods	1.4		
		302.5	91	-211.5

Rationale: C2K will make extensive use of automatic, computerized network of T&CO and launch countdown hardware and software. STS scope does not include CCMS for DOD, MBAC and CITE. Grossly simpler C2K vehicles and reduction from 3 to 2 prime vehicle elements should reduce C2K workload by 70%. C2K has only 2 LCC-type firing rooms. (.5 x .67) = .5 vehicle simplicity and automation; .67 less vehicles.

1.4.2	LPS Maintenance and Support Engineering			
1.4.2.1	LPS Maint.& Support Eng.	73.0	22	-51.0

Rationale: Same as 1.4.1; C2K reduces this STS-related workload by 70%.

1.4.3	Instrumentation, Measurements & Calibration			
1.4.3.1	Field/In-Place Cal.	31.4		
1.4.3.3	Instrumentation & Meas.	68.0		
1.4.3.4	Calibration Mods	0.8		
1.4.3.5	Inst. & Measurement Mods	3.0		
		103.2	31	-72.2

1.4.4	Integrated Ground Opers. Support			
1.4.4.1	Planning & Scheduling	19.9		
1.4.4.2	Config./Data Management	48.9		
		68.8	21	-47.8

Rationale: Same as 1.4.1 and 1.4.2; C2K reduces this STS-related workload by 70%.

APPENDIX A
C2K GROUND PROCESSING HEADCOUNT ESTIMATION BY APPLICATION OF STS WBS

STS WBS		STSHC	C2KHC	△
1.5	Facility/Support Equip. Engineering	101.3	26	-75.3

1.5.1	Support Eng. Mgmt. & Control			
1.5.1.1	Support Eng. Mgmt. & Control	7.2	2	-5.2

Rationale: STS scope plans and directs engineering support to Shuttle processing facilities and support equipment. C2K facilities and GSE are 1/2 of STS. Management expedited by interactive computer networks. C2K work reduced by 75%.

1.5.2	Support Engineering			
1.5.2.1	System Integration	11.5		
1.5.2.2	Design Engineering	47.0		
		58.5	15	-43.5

Rationale: Scope provides engineering support for processing facilities and GSE. C2K has 1/2 facilities, and 1/2 GSE of STS. System and design engineering expedited by computerized design aids, CAD-CAM, etc. Workload reduced 75%.

1.5.3	Configuration Management Support			
1.5.3.1	Conf. Mgmt Support	7.8	2	-5.8

Rationale: STS scope provides operation of a CIB in support of CCB; operation of CCB excluded. C2K workload reduced 75%.

1.5.4	Special Engineering Projs.			
1.5.4.1	Special Engrg. Projs.	27.8	7	-20.8

Rationale: STS scope provides facilities and GSE modifications package engineering. Management and design engineering expedited by computer aids. C2K workload reduced by 75%.

APPENDIX A

C2K GROUND PROCESSING HEADCOUNT ESTIMATION BY APPLICATION OF STS WBS

STS WBS		STSHC	C2KHC	Δ
1.6	Program Support	581.4	146	-435.4

1.6.1	SR&QA			
1.6.1.1	Safety	42.2	11	-31.2

Rationale: Scope is management of safety and does not include performance during discrete processing, O&M or activation. C2K major facilities area 1/2 of STS, prime vehicle elements reduced from 3 to 2, barren pad, no MLP/CT, no hypergols, no hazardous lift of vehicles off of ground, and headcount appraoches 40% of STS. C2K workload reduced by 75%.

1.6.1.2	Reliability	12.3	3	-9.3

Rationale: Scope includes management of reliability support and control of reliability engineering. C2K facilities are 1/2 of STS, prime vehicle elements reduced from 3 to 2, GSE reduced to about 1/2 of STS. C2K workload reduced by 75%.

1.6.1.3	QA	97.6	24	-73.6

Rationale: Scope includes management of overall quality program; does not include field inspection and test. Prime effort is maintenance of R, M&Q Plan, QPRDs, PRACA, etc. C2K facilities are 1/2 of STS, vehicles reduced from 3 to 2, GSE reduced to about 1/2. Documentation expedited with computer aids; word-processing, etc. C2K workload reduced by 75%.

1.6.2	Logistics			
1.6.2.1	Logistics Engineering	97.1		
1.6.2.2	Systems & Audits	27.8		
1.6.2.4	Supply	180.2		
1.6.2.5	Transportation	48.6		
1.6.2.6	Procurement	49.7		
		403.4	101	-302.4

Rationale: C2K facilities 1/2 of STS, vehicles 2/3 of STS, GSE 1/2 of STS. Logistics expedited by computer-aided documentation and automated retrieval such as mini-load. C2K workload reduced by 75%.

APPENDIX A

C2K GROUND PROCESSING HEADCOUNT ESTIMATION BY APPLICATION OF STS WBS

STS WBS		STSHC	C2KHC	Δ
1.6.3	Information and Data Mgmt.			
1.6.3.2	Office Services	25.9	7	-18.9

Rationale: Scope includes printing, repro machine, vital records preparation and storage, central word processing, mail, telephones, etc. C2K implements computerized network of telemail, command and reporting media. Overall scope greatly reduced by less facilities, simpler vehicle and associated processing. C2K workload reduced by 75%.

1.7	Program Management	662.1	341	321.1

1.7.1	General Management			
1.7.1.1	General Manager/Staff	21.4	21	-.4

Rationale: STS scope includes Program Management, PAO, Counsel, and Safety Advisory Council. C2K top management structure assumed commensurate to STS.

1.7.1.2	Directorates	227.4	150	-77.4

STS scope includes about 28 1st level and 9 2nd level Directorates and administrative/engineering staffs. If each Directorate, in theory, has a Director and a secretary, this leaves 153 HC performing staff studies, data/fact gathering, report and status preparations, and the multitude of documentation required to support this very complex system and its associated technical/contractual requirements. C2K is envisioned as a much simpler vehicle, with simpler and less facilities, less integrated vehicle processing/checkout and less payload interaction. This simpler configuration supported by a network of computerized tele-mail, scheduling, reporting, status keeping, and rapid command media is estimated to reduce the staff requirement at this level by 50%.

1.7.2	Program Controls			
1.7.2.2	Planning & Coordination	30.5	15	-15.5
1.7.2.3	PPMS Development/Procedures	35.3	18	-17.3

Rationale: 50% reduction attributed to full implementation of computerized network for resources management and control.

APPENDIX A

C2K GROUND PROCESSING HEADCOUNT ESTIMATION BY APPLICATION OF STS WBS

STS WBS		STSHC	C2KHC	Δ
1.7.3	Finance and Contracts			
1.7.3.1	Accounting	33.9	17	-16.9
1.7.3.2	Program Financial Controls	16.1	6	-10.1
1.7.3.3	Contracts	8.8	6	- 2.8

Rationale:

.1 Work load reduced by 50%: C2K has 1/2 of equivalent STS major facilities; 4 simpler vehicle and systems, and headcount approaching 30% of STS.

.2 Same as .1, plus deletion of VLS activities. Work load reduced by approx. 65%.

.3 Deletion of VLS activities. Work load reduced by approximately 30%. Quantity of C2K contracts by function and type considered commensurate with STS.

1.7.4	Human Resources			
1.7.4.1	Employment	15.8	4	-11.8

Rationale: C2K has 1/2 of STS-equal major facilities and a HC about 40% of STS. C2K workload reduced approximately 75%.

1.7.4.2	Compensation and Benefits	13.9	4	-9.9

Rationale: Same as 1.7.4.1.

1.7.4.3	Security	17.1	9	-8.1

Rationale: C2K has 1/2 of STS-equal major facilities. Payloads are received/inserted in autonomous (secure cocoon canister) and have nearly no vehicle/pad interface. Basic C2K security management structure commensurate with STS. C2K workload reduced by approximately 50%.

1.7.4.4	Employee Relations	20.1	5	-15.1

Rationale: C2K HC is about 40% of STS equivalent. Workload reduced approximately 75%.

1.7.4.5	Human Resources Development	8.4	4	-4.4

Rationale: Scope is primarily training. New facilties, new vehicles, very few directly experienced personnel. Workload reduced 50%.

APPENDIX A

C2K GROUND PROCESSING HEADCOUNT ESTIMATION BY APPLICATION OF STS WBS

STS WBS		STSHC	C2KHC	△
1.7.4.6	Equal Employment Opportunity	3.0	1	-2

Rationale: C2K HC is 40% of STS. EEO staffed to minimum level for C2K.

1.7.5	Operations Management			
1.7.5.1	Manifest Planning	34.6	9	-25.6

Rationale: Payload configuration impact on C2K is eliminated by autonomous payload container. Work will continue in coordination with external agencies, launch rate assessment and payload capabilities, loading analyses vs. mission performance, etc. C2K workload reduced approximately 75%.

1.7.5.2	Mission Management	5.9	3	-2.9

Rationale: STS scope is analysis/acceptance of non-standard flight element changes. Standardized/autonomous payload containers greatly reduce mods/changes. C2K workload reduced 50%.

1.7.5.3	Configuration Mgmt.	34.8	17	-17.8

Rationale: STS scope assumes commonality between KSC and VLS and evaluation of proposed changes, tracking status of flight hardware/software mods and operation of Level IV CCB etc. C2K workload eliminates VLS impact; workload reduced 50%.

1.7.6	Training			
1.7.6.1	SPC Outside Training	3.9	2	-1.9

Rationale: New C2K facilities, new vehicle, very few directly experienced personnel. C2K HC 40% of STS. C2K workload 50% of STS.

1.7.6.2	Training at KSC	67.9	34	-33.9

Rationale: Same as .1, except on-line training function more directly impacted by smaller headcount. C2K workload reduced by 50%.

1.7.7	Shuttle Processing Data Management Systems (SPDMS)			
1.7.7.1	SPDMS Req. Definition & Plng.	17.9	9	
1.7.7.2	SPDMS Dev. & Implementation	11.9		
1.7.7.4	SPDMS Mods	6.6		
		36.4	9	-27.4

Rationale: C2K major facilities are 1/2 STS, prime vehicle elements reduced from 3 to 2, barren pad, no MLP/CT and headcount approaches 40% of STS. STS scope includes shuttle processing planning, scheduling, configuration management. Scope presumed unchanged and VLS coordination eliminated. Simpler vehicle, systems, facilities, and GSE reduce C2K workload by 75%.

APPENDIX A
C2K GROUND PROCESSING HEADCOUNT ESTIMATION BY APPLICATION OF STS WBS

STS WBS		STSHC	C2KHC	△
1.7.8	Lockheed Mgmt Info. System (LMIS)	3.7		
1.7.8.1	LMIS Requirements Def. & Planning	4.8		
1.7.8.2	LMIS Development & Impl.	5.3		
1.7.8.3	LMIS Opers. & Maintenance	7.3		
1.7.8.4	LMIS Mods	5.8		
		26.9	7	-19.9

Rationale: Same as 1.7.7.

1.8	Production - Second Line Facilities	323.1	0	-323.1

Rationale: STS workload includes Pad B, MLP3, VAB HB1 commonality mods, LPS upgrade, Pad B/MLP3 Spares, new CLS activation, Pad B/MLP3 early turnover. These items not applicable to C2K.

1.9	Communications	223.2	148	-75.2

1.9.1.1	Voice Communications O&M	83.4	42	-41.4
1.9.1.2	Voice Comm. Mods	5.1	3	- 2.1

Rationale: Pads communications systems cut to .1 of STS, no VAB, LCC cut to .5, no HMF.

1.9.2.1	Wideband Transmission and Nav. Aids O&M	64.1	64	-.1
1.9.2.2	Wideband Transmission and Nav. Mods	3.9	4	+.1

Rationale: C2K assumed autonomous and separate from STS with nearly the same flight, ground and CLS work scope.

1.9.3.1	Support Services O&M	57.2	29	-28.2

Rationale: This STS Voice Communications workload reduced for C2K by same factors as 1.9.1.1 and 1.9.1.2.

1.9.4.1	Communications Planning and Requirements	9.5	6	-3.5

Rationale: This element supports all WBS 1.9 activity. C2K headcount prorated on above items to 66% of STS.

1.10	DOD Support	172.4	86	-86.3

APPENDIX A
C2K GROUND PROCESSING HEADCOUNT ESTIMATION BY APPLICATION OF STS WBS

STS WBS		STSHC	C2KHC	Δ
1.10.6.2	ELS OFS		0.8	
1.10.8.1	Secure LPS		57.3	
1.10.8.2	Secure Communications		14.2	
1.10.8.3	Security Planning Info. and Analysis		8.3	
1.10.8.5	Facility O&M		4.3	
1.10.8.6	Security Training		0.3	
1.10.8.7	Secure LPS Modifications		0.9	
		172.4	86.0	-86.3

Rationale: All unlisted 1.10 WBS items are for direct support to VLS. C2K is not VLS-linked. 1.10 items listed above are unchanged from existing STS mode and represent secure operations of two control rooms as envisioned for C2K for redundancy, plus uncompleted orbital mission work.

		STSHC	C2KHC	Δ
1.11	Marshall Booster Assy. Contract	12.3	0	-12.3

Rationale: No STS SRBs on C2K and no related MBAC.

		STSHC	C2KHC	Δ
1.12	Cargo Support	35.3	4	-29.3

Rationale: C2K payload is containerized and autonomous. Order-of-magnitude HC decrease to provide only schedule and coordination.

		STSHC	C2KHC	Δ
1.13	Centaur Project	68.6	0	-68.6

Rationale: C2K does not provide support.

		STSHC	C2KHC	Δ
1.14	Uniquely Funded Operations	8.0	4.0	-4.0
3.0	Specially Negotiated Projects at KSC	38.2	19	-19.2

Rationale 1.14 and 3.0: All programs historically require small percentage of unique or special projects. C2K assumed at 1/2 STS.

APPENDIX B

C2K GROUND PROCESSING TIME ESTIMATION BY APPLICATION OF 51-L TIMELINE

NOTES:

1. Hours included in the functional titles (A-W) are 160-hour turnaround design goals set by Level I for STS.

2. Hours tabulated under the column heading "51-L" are actual clock hours (not total manhours) required to process 51-L.

3. Hours tabulated under Circa 2000 "(C2K)" are those clock hours estimated by this study for the C2K orbiter (ORB), and booster (BSTR) where appropriate, by application of C2K guidelines and assumptions. The parenthetical (xhr.BAR) refers to the turnaround barchart time allotted by functional assessment of activities, i.e., estimated clock hours have been broken into parallel activities.

APPENDIX B
C2K GROUND PROCESSING TIME ESTIMATION BY APPLICATION OF 51-L TIMELINE

A. LANDING AREA 1.0 HR.

WAD	TITLE	51-L (HOURS)	C2K ORB (HOURS)	C2K BSTR (HOURS)
V5001	SLF OPS/TOW TO OPF*	10.5	2 (2 hr BAR)	2

(C2K virtually eliminates STS "camel caravan"; no hypergols, no APU, no ground power, etc.)

* Previous mission landed at DFRF and was ferried to KSC on the SCA.

B. SAFING AND DESERVICING 5.0 HRS.

WAD	TITLE	51-L (HOURS)	C2K ORB (HOURS)	C2K BSTR (HOURS)
V5001	TOW ORB INTO OPF/JACK & LEVEL /POWER UP PREPS	17.5	4	4
V1184	SAFING PATCHES/LOAD MMU	3.0	1	1
V1091	PRSD CRYO VENT (C2K service on-board elec. pwr. supply)	40.0	6	6
V1158	OMS TRICKLE PURGE & OMS/RCS DESERV.	96.0	4	4
V5012	NOSE LANDING GEAR THRUSTER REMOVAL	8.0	0	0
V5012	PYRO WIRE HARNESS R&R RESISTANCE CK.	48.0	0	0
V1u78	APU LUBE OIL DESERVICING	24.0	0	0
N/A	MPS/SSME PROCESSING (ENGINE DRYING)	71.0	6	6
V1018	WATER SPRAY BOILER DESERVICING	24.0	0	0
VII96	APU POST FLIGHT FUEL SYSTEM OPS	85.0	0	0
	TOTAL	416.5	21 (8 hr BAR)	21

(C2K: No hypergols, no APU, no WSB, no pyro on L/G)

C. PAYLOAD REMOVAL PREPS. 5.0 HRS.

WAD	TITLE	51-L (HOURS)	C2K ORB (HOURS)	C2K BSTR (HOURS)
V3512	INSTALL PAYLOAD ACCESS	8.0	2	
V5006	PAYLOAD STRONGBACK INST/OPEN PAYLOAD BAY DOORS	17.0	2	
	TOTAL	25.0	4 (4 hr BAR)	

(C2K: Remove payload canister/cocoon; load onto MMSE; upload inserted Item J.)

D. MISSION UNIQUE PAYLOAD ACCOMMODATION EQUIPMENT REMOVAL/INST. 27.0

WAD	TITLE	HOURS 51-L	C2K ORB	C2K BSTR
N/A	AFT FLIGHT DECK/PAYLOAD BAY DECONFIG/RECONFIG.	240.0	0	
V1175	RMS TURNAROUND VERIF.	16.0	0	
V5R03	PRSD H2/02 TANK SET 4 REMOVAL	120.0	0	
N/A	PCP/CIU INSTALLATION	48.0	0	
N0533	PCP/CIU CHECKOUT	5.5	0	
	TOTAL	429.5	0	

(C2K: Payload autonomous from Orbiter)

E. ORBITER SCHEDULED MAINTENANCE 24.0 HRS.

WAD	TITLE	HOURS 51-L	C2K ORB	C2K BSTR
V6002	ORBITER POST FLIGHT INSPECTION	24.0	8	8
V1026	REMOVE WASH & WASTE FUNCTIONAL	16.0	0	0
V5017	DESTOW FCE	16.0	0	0
V1084	CAUTION & WARNING SYS VERIFICATION	8.0	2	2
V5056	REMOVE GAS SAMPLE BOTTLES	8.0	2	2
V1134	WATER DRAIN (HORIZONTAL POSITION)	8.0	0	0
V1007	PV&D VENT FILTER/INSTL.	104.5	4	4
V1076	WCCS FUNCTIONAL CHECKS	176.0	0	0
V1062	AIR DATA SYSTEM	8.0	0	0
V1008	MSBLS TESTING	8.0	1	1
V1200	RECORDER DUMP	8.0	1	1
V6005	STARTRACKER CLEAN/INSPECT	8.0	4	0
V6018	CABIN AIR/RECIRCULATE MAINTENANCE	120.0	0	0
V6012	HYD INSPECTION	16.0	0	0
V1217	ECLSS ARPCS FUNCTIONAL TEST	12.0	0	0
V1178	KU BAND TURNAROUND C/O	8.0	2	0
V1184	LOAD MMU	12.0	4	0
V1005	VTR C/O	4.0	4	0
V1086	MEC PIC TEST (C2K eng. ign. sys.)	44.0	4	4
V5069	TRANSFER TO AFT 999 JACKS	3.0	0	0
V1016	VENT DOOR FUNCTIONAL	11.0	4	4
V1097	ET DOOR FUNCTIONAL/LATCH FOR FLIGHT	8.0	4	0
V5069	TRANSFER TO AFT 570 JACKS	3.0	0	0
V1026	REMOVE WASTE COLLECTION SYSTEM & WASTE FLUSH	24.0	0	0
V1153	APU WATER SERVICING	48.0	0	0
V1099	STARTRACKER DOOR FUNCTIONAL	5.0	4	0
V1042	SMOKE DETECTION & FIRE SUPRESSION FUNCTIONAL	4.0	4	4
V5010	INSTALL B/C/ELBOW CCTV	8.0	0	0
V1003	POWER SYSTEM VALIDATION	23.0	4	4
V1180	FRCS FUNCTIONAL C/O (LPS)	14.0	2	0
V1080	MULT CRT DISP SYS C/O (LPS)	4.0	0	0
V1098	LANDING GEAR FUNCTIONAL	4.0	4	4
V6034	CREW MODULE SEAT FUNCTIONAL	8.0	0	0

APPENDIX B

C2K GROUND PROCESSING TIME ESTIMATION BY APPLICATION OF 51-L TIMELINE

			HOURS	
		51-L		C2K
WAD	TITLE		ORB	BSTR
V1005	CCTV SYSTEM TEST	3.0	0	0
V1183	ORBITER ELECTRICAL SYSTEM VALIDATION (LPS)	12.0	2	2
V1078	APU LUBE OIL SERVICING	66.0	0	0
V1041	N2 SERVICING	8.0	4	4
V9023	CLOSE/OPEN PAYLOAD BAY DOORS	11.0	2	0
V1180	AFT OMS/RCS FUNCTIONAL	96.0	8	0
V1037	NH3 SYSTEM SERVICING	24.0	0	0
V1055	POTABLE WATER SERVICING	24.5	0	0
V1017	WATER SPRAY BOILER SYSTEM LEAK & FUNCTIONAL	25.0	0	0
V9002	BRAKE FILL & BLEED	4.0	4	4
V1048	NOSE WHEEL STEERING	5.0	4	4
V1065	BRAKE/ANTI-SKID CONTROL SYSTEM TEST (LPS)	8.0	2	2
V1060	AEROSURFACE CHECKOUT	5.5	4	4
V6034	GALLEY FUNCTIONAL	8.0	0	0
V5050	FLIGHT CREW EQUIPMENT STOWAGE/CEIT/DESTOWAGE	19.0	0	0
TPS	FLIGHT CREW EQUIPMENT INFLIGHT MAINTENANCE WALKDOWN	3.0	0	0
V9001	STOW KU BAND ANTENNA	8.0	4	0
V1131	HYDRAULIC ACCUMULATOR CHECKS	8.0	0	0
V1161	ORBITER BUSS REDUNDANCY	19.0	2	2
	TOTAL	1132.5 (38 hr BAR)	98	60

ASSUMPTIONS:

Extensive BITE and computerized auto test, no NH3, no hydraulics, no pyrotechnics in engines (electrical ignition), no APU, unpiloted vehicles (autonomous passenger module). 51-L expended 441.5 hrs. of this function (39.0%) on manned systems. C2K can have significant percentage of unmanned flights. Passenger module support is offline (similar to payload support) and not accounted here. C2K Orbiter functions above assessed at 36 hrs electrical/ electronic; 38 hrs mechanical; 24 hrs inspection/ fluids; propulsion.

F. PROPULSION SYSTEM SCHEDULED MAINTENANCE 24.0 HRS.

			HOURS	
		51-L		C2K
WAD	TITLE		ORB	BSTR
V9002	HYDRAULIC POWER UP PREPS & POSITION SSME'S	49.0	0	0
V5043	REMOVE HEAT SHIELDS	20.0	4	4
V1009	MPS LEAK & FUNCTIONAL	176.0	16	16
V1011	SSME LEAK & FUNCTIONAL	176.0	16	16
V5058	REMOVE SSME #2	5.5	0	0
TPS	NOZZLE WELD INSPECTION (VAB)	*240.0	24	24
V5E06	SSME #1 HIGH PRESSURE FUEL TURBOPUMP R&R	37.0		
V5E06	SSME #2 HIGH PRESSURE FUEL TURBOPUMP R&R (VAB)	*40.0	16	16
V5E29	SSME #2 GIMBAL BOLT R&R	*32.0		
V5057	DISCONNECT SSME TVC'S/INSTALL STIFF ARMS	4.0	0	0

APPENDIX B
C2K GROUND PROCESSING TIME ESTIMATION BY APPLICATION OF 51-L TIMELINE

F. PROPULSION SYSTEM SCHEDULED MAINTENANCE (Continued)

		HOURS		
		51-L	C2K	
VAD	TITLE		ORB	BSTR
V5005	INSTALL SSME #2	20.0	0	0
V1063	SSME TVC FLIGHT CONTROLS	3.0	3	3
V1011	SSME FLIGHT READINESS TEST	13.0	4	4
V1001	SSME ELECTRICAL INTERFACE VERIF.	8.0	2	2
V9019	MPS VJ LINES CHECK	4.0	4	4
V5057	REMOVE STIFF ARMS/CONNECT SSME TVC'S	8.0	0	0
V5043	HEAT SHIELD INSTALLATION	57.5	8	8
	TOTAL	893.0	97 (36 hr BAR)	97

C2K functions above assessed at 36 hrs heat shields/nozzle weld insp; 3 engine L&F/pumps;

* These operations were accomplished in the engine shop in the VAB.

G. UNSCHEDULED MAINTENANCE & SYSTEM REVERIFICATION 50.0 HRS.

		HOURS		
		51-L	C2K	
VAD	TITLE		ORB	BSTR
N5230	ORBITER POST FLIGHT TROUBLESHOOTING (C2K; .5)	64.0	32	32
V1053	REMOVE CABIN SENSOR	8.0	0	0
V7253	WINDOW POLISHING	112.0	0	0
N/A	ORBITER POST FLIGHT TROUBLESHOOTING (C2K; .5)	32.0	16	16
IPR	TANK #1 H2 CRYO CONTROL HEATER TROUBLESHOOTING	48.0	24	24
V5R01	FUEL CELL #1 REMOVAL (Design C2K equivalent for access; .1)	64.0	6	6
IPR	MSBLS TROUBLESHOOTING	3.0	:	
PR	REMOVE MSBLS	1.0	: 4	4
V1165	LANDING/BRAKE INSTALLATION (brake design improved; .1)	24.0	2	2
PR	R&R LAUNCH CONTROL AMPLIFIER	3.0	3	3
V5U01	REMOVE APU #3 (no APU)	31.0	16	16
V5011	R&R RH OMS POD	29.0	15	15
V5079	OMS ENGINE HEAT SHIELD REMOVAL	16.0	8	8
V1164	ELEVON LOWER COVE SEAL PRESS LEAK RATE	24.0	24	24
V5U01	REINSTALL APU #3 (no APU)	16.0	8	8
V5016	TRANSFER RIGHTHAND OMS POD TO HMF	2.0	1	1
PR	R&R HEADS UP DISPLAY UNIT (SIMPLER L/G DESIGN; NO PYRO)	8.0	0	0
TPS	AMMONIA TANK PURGE	16.0	0	0
V1165	LANDING GEAR BRAKE INSPECTION & BRAKE R&R (C2K: .1)	23.0	2	2
TPS	NH3 LEAK & FUNCTIONAL	16.0	0	0
V1225	RIGHT OMS INTERFACE TEST	32.0	16	16

G. UNSCHEDULED MAINTENANCE & SYSTEM REVERIFICATION (Continued)

WAD	TITLE	HOURS 51-L	C2K ORB	C2K BSTR
V5R01	INSTALL FUEL CELL #1	11.5	2	2
V1165	INSTALL NOSE LANDING GEAR TIRES	8.0	8	8
V1177	HEADS UP DISPLAY CHECKOUT	3.0	0	0
TPS	MATE APU FUEL LINES	13.0	7	7
IPR	LEAK IN APU FUEL LINE "B"NUT	16.0	8	8
V5079	LEFTHAND OMS ENGINE HEAT SHIELD INST'L R/T & LK CK	16.0	8	8
V1180	AFT OMS/RCS FUNCTIONAL	4.0	2	2
PR	INSTALL THRUSTER & RETEST (C2K; simpler design; no pyro)	8.5	0	0
V1226	OMS POD MATING	16.0	8	8
V1053	CABIN SENSOR INSTALLATION & RETEST	8.0	0	0
IPR	REMOVE BREAK OUT BOXES	2.0	2	2
PR	LEFT OMS CROSSFEED LINE PROBLEM	22.5	11	11
V5011	R&R LEFTHAND OMS POD	26.5	13	13
V1224	OMS POD ELECTRICAL CONNECT & RETEST	12.5	6	6
V1226	LEFTHAND OMS CROSSFEED CONNECT	5.0	3	3
V1161	BUSS REDUNDANCY LEFTHAND OMS POD	9.0	5	5
	TOTAL	753.5	260 (48 hr BAR)	260

ASSUMPTIONS:

C2K-equivalent OMS/RCS system assumed one-half as complex and O&M intensive as STS. C2K-equivalent APU (batteries and/or high density fuel cells) assumed one-half as complex and O&M instensive as STS. C2K Orbiter functions above assessed at 95 hrs electrical power; 44 hrs electronics; 36 hrs airframe; 85 hours propulsion. 48 hrs series impact estimate requires dual power and propulsion crews working in parallel.

51-L expended 155.0 hrs. of this function (20.6%) on manned systems. C2K can have significant percentage of unmanned flights. Passenger module support is offline (similar to payload support) and not accounted here.

H. TPS REFURBISHMENT 40.0 HRS.

WAD	TITLE	HOURS 51-L	C2K ORB	C2K BSTR
V6028	ORBITER POST FLIGHT TPS INSPECTION	N/A :	8	
V9024	ORBITER TPS MAINTENANCE/OPERATION	N/A : 60	8	
N/A	ORBITER TPS WATERPROOFING	N/A 168	0	
V9022	ET DOOR CYCLES/TPS OPERATIONS	120.0	4	
V6035	RSI PRE ROLLOUT INSP & UPPER SURFACE WATERPROOFING	71.0	0	
	TOTAL	191.0	20 (20 hr BAR)	

H. TPS REFURBISHMENT 40.0 HRS. (Continued)

NOTE: The 51-L as-run schedule shows the first three above operations starting as soon as the Orbiter is rolled into the OPF but does not identify how long they continue. The STS-XX schedule allows 60 hrs. for both the inspection and the maintenance operation and 168 hrs. for the waterproofing.

I. ORBITER INTEGRATED TEST 12.0 HRS.

NOTE: The requirement for this test has been deleted from the OMRSD.

J. PREPS FOR MATING 10.0 HRS.

WAD	TITLE	HOURS 51-L	C2K ORB	C2K BSTR
V5012	AFT SEP HARNESS/ET UMB GSE & PLUG INSTALLATION	8.0	0	8
V5012	FWD ET BEARING & YOKE INSTALLATION	32.0	0	0
V5012	PRE-OPS SET UP (no pyro)	16.0	0	0
V5012	POWER DOWN ORDNANCE INSTALLATION (no pyro)	8.0	0	0
V5012	POWER ON PIC TEST (no pyro)	8.0	0	0
V6034	PAYLOAD BAY SHARP EDGE INSPECTION	4.0	0	0
V1032	ORBITER CLOSEOUT	104.0	8	4
V1032	ORBITER AFT CLOSEOUT	85.5	4	4
V6003	PAYLOAD BAY CLOSEOUT/INSPECTION	20.0	0	0
V9021	DEACTIVATE TRICKLE PURGE	8.0	2	2
V1176	PAYLOAD BAY CLEANING	27.5	2	0
V5018	CLOSE PAYLOAD BAY DOORS & REMOVE STRONGBACKS (C2K insert P/L, close PBD)	16.0	8	0
V9002	HYD OPS/POSITION AEROSURFACES FOR ROLLOUT (no hyd.)	4.5	2	2
V3555	DISCONNECT ORBITER PURGE AIR	5.0	2	2
V3515	REMOVE LH2/LO2 CARRIER PLATES	5.0	2	2
V5101	JACKDOWN WEIGH & CG/PREP TO TOW	8.0	4	2
	TOTAL	359.5	34 (14 hr BAR)	26

K. TOW ORBITER TO VAB NO TIME ALLOTTED

WAD	TITLE	HOURS 51-L	C2K ORB	C2K BSTR
S0004	ORBITER TOW & MATE (C2K; no VAB scenario)	.5	0	
	TOTAL	.5	0	

APPENDIX B
C2K GROUND PROCESSING TIME ESTIMATION BY APPLICATION OF 51-L TIMELINE

L. TRANSFER AISLE ORBITER PREMATE OPS 5.0 HRS.

WAD	TITLE	HOURS 51-L	C2K ORB	C2K BSTR
S0004	ORBITER TOW & MATE	18.5	0	
	TOTAL	18.5	0	

M. ORBITER MATE AND INTERFACE VERIFICATION 15.0 HRS.

WAD	TITLE	HOURS 51-L	C2K ORB	C2K BSTR
S0004	ORBITER TOW & MATE	103.0	0	0
S0008	SHUTTLE INTERFACE VERIFICATION (C2K computerized auto T&CO)	36.5	0	0
S0020	SRB TESTING (C2K; no SRB)	5.5	0	0
	TOTAL	144.0	0	0

N. SHUTTLE INTERFACE TEST 19.0 HRS.

NOTE: The requirements for this test have been removed from the OMRSD and are no longer being accomplished.

O. MOVE TO PAD 7.0 HRS.

WAD	TITLE	HOURS 51-L	C2K ORB	C2K BSTR
A5214	TRANSFER & MATE TO PAD B (C2K; tow to pad, erect, retract L/G)	13.5	6	6
	TOTAL	13.5	6 (6 hr BAR)	6

P. MLP MATE TO PAD & LAUNCH PAD VALIDATION 3.0 HRS.

WAD	TITLE	HOURS 51-L	C2K ORB	C2K BSTR
S0009	LAUNCH PAD VALIDATION (C2K; barren pad)	9.5	2	
N/A	POWER UP PREPS	30.0	2	
	TOTAL	39.5	4 (2 hr BAR)	

APPENDIX B
C2K GROUND PROCESSING TIME ESTIMATION BY APPLICATION OF 51-L TIMELINE

Q. PAYLOAD INSTALLATION IN PCR (C2K OPF) 13.0 HRS.

WAD	TITLE	HOURS 51-L	C2K ORB	C2K BSTR
N0133	CARGO INSTALLATION IN PCR PAD B	35.5	0	
N/A	WIND DELAY IN INSTALLING CARGO IN PCR	33.0	0	
N/A	IUS SCU PROBLEM	32.5	0	
N1533	TDRS PROPELLANT LOAD	33.5	0	
N/A	IUS POWER UP/DOWN TEST	21.5	0	
N/A	IUS STANDALONE TEST (Payloads are autonomous "cargo boxes"; installed horizontally at an OPF equivalent)	18.0	0	
	TOTAL	174.0	0	

R. FUEL CELL DEWAR LOADING 10.0 HRS.

WAD	TITLE	HOURS 51-L	C2K ORB	C2K BSTR
V2303	DEWAR LOAD	6.5	0	
	TOTAL	6.5	0	

NOTE: The 160 hrs turnaround schedule has this activity to occur prior to the arrival of the vehicle at the pad. During the 51-L flow, it was accomplished just prior to hyper load which caused another pad clear in the pad operation.

S. SHUTTLE LAUNCH READINESS VERIFICATION 6.5 HRS.

WAD	TITLE	HOURS 51-L	C2K ORB	C2K BSTR
S0009	LAUNCH PAD VALIDATION WITH APU HOT FIRE (no APU)*	40.0	0	
V1202	HE SIGNATURE TEST	17.5	1	
	TOTAL	57.5	1 (1 hr BAR)	

* This time includes 4.5 hrs. for emergency power down if the Orbiter cooling was lost to the vehicle.

T. PAYLOAD INSTALLATION AND LAUNCH READINESS VERIFICATION 9.0 HRS.

		HOURS		
		51-L	C2K	
WAD	TITLE		ORB	BSTR
N0133	CARGO PAYLOAD BAY OPERATIONS	80.0	0	
S0017	TERMINAL COUNT DEMONSTRATION TEST	55.5	4	
V9023	OPEN PAYLOAD BAY DOORS	1.5	0	
S0009	1ST MOTION CHECKS & SRSS HOLDFIRE CHECKS	6.0	1	
N/A	HOT GAS SYSTEM TROUBLESHOOTING	15.0	0	
V1202	HOT GAS POI'S	7.5	0	
V1149	AFT CAVITY PURGE	9.5	1	
PR	PDI R&R AND RETEST	5.0	0	
B1500	R&R SRB AFT IEA	8.5	0	
N0433	IUS TDRS IVT/ETE	25.0	1	
IPR	R&R HIM 6893	2.5	0	
PR	IEA ELECTRICAL CONNECT & RETEST	12.5	0	
N/A	POD TOTALIZER CONNECT & RETEST	13.0	0	
PR	UPS 40 TROUBLESHOOTING/CARD CHANGE/RETEST	8.5	0	
N/A	CHARGE CARGO BATTERIES	15.5	0	
V1077	FUEL CELL #1 SERVICING (This item reduced to launch readiness assessment for C2K)	8.0	0	
	TOTAL	273.5	7 (4 hr BAR)	

U. CABIN CLOSEOUT 1.0 HR.

	51-L	C2K
U. CABIN CLOSEOUT 1.0 HR.	0	2 (2 hr BAR)

NOTE: No serial time was allotted during 51-L pad operations to close the crew cabin prior to propellant loading. (C2K: passenger transit to pad and ingress via mobile manlift, closeout, and HE evacuation).

V. HAZARDOUS SERVICING/SERVICE DISCONNECTS 8.5 HRS.

		HOURS		
		51-L	C2K	
WAD	TITLE		ORB	BSTR
S0024	PRE LAUNCH PROPELLANT LOAD	202.5	8	
T1401	ET BLANKING PLATE REMOVAL	5.5	2	
N/A	PAYLOAD DISCONNECT/ PLB CLOSEOUT/PLB DOORS CLOSE	7.0	0	
PR	R&R RJDA #2 & RETEST	9.5	0	
PR	R&R QD & RETEST OMS REG. LOCK UP TEST	8.0	0	
S0009	ORDNANCE INSTALLATION	37.0	0	
N/A	CARRIER PANEL INSTALLATION	37.0	0	
S5009	ORBITER AFT CLOSEOUT	75.0	0	
S1005	ET PURGES	12.0	0	

V. HAZARDOUS SERVICING/SERVICE DISCONNECTS (Continued)

The following operations were performed during this block of time but were not part of the original timelines.

N/A	CARGO STANDALONE OPS (C2K; pad access via computer only)	88.0	1
V1103	EMU INSTALLATION & TEST (C2K; EMU installed at OPF equivalent)	16.0	0
V9002	SSME VALVE CYCLES/FRT'S	32.0	1
V1184	MMU FLIGHT LOAD	14.0	1
	TOTAL	543.5	13 (8 hr BAR)

V. LAUNCH FROM STANDBY 2.0 HRS.

VAD	TITLE	51-L	HOURS C2K ORB.......BSTR
S0007	LAUNCH COUNTDOWN	121.5	2
	TOTAL	121.5	2 (2 hr BAR)

NOTE: The length of countdown for the 51-L mission was much longer due to several delays caused mainly by weather. The first one was bad visibility at the transatlantic landing site (dust storm in North Africa). Possible adverse weather at the launch site then caused a 24 hour delay, and on the third attempt, high cross winds caused a scrub at T-9 minutes.